REPORT

OF THE

SEVENTY-NINTH MEETING OF THE

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE

WINNIPEG: 1909

AUGUST 25—SEPTEMBER 1

LONDON
JOHN MURRAY, ALBEMARLE STREET
1910

Office of the Association: Burlington House, London, W.

CONTENTS.

REPORTS ON THE STATE OF SCIENCE.

TRANSACTIONS OF THE SECTIONS.

[*An asterisk * indicates that the title only is given. The mark † indicates the same, but with a reference to the Journal or Newspaper in which it is published* in extenso.]

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

THURSDAY, AUGUST 26.

FRIDAY, AUGUST 27.

DEPARTMENT OF MATHEMATICS.

DEPARTMENT OF GENERAL PHYSICS.

DEPARTMENT OF COSMICAL PHYSICS.

MONDAY, AUGUST 30.

TUESDAY, AUGUST 31.

Department of General Physics.

Department of Cosmical Physics.

WEDNESDAY, SEPTEMBER 1.

Department of General Physics.

Department of Cosmical Physics.

Section B.—CHEMISTRY.

THURSDAY, AUGUST 26.

SECTION C.—GEOLOGY.

THURSDAY, AUGUST 26.

FRIDAY, AUGUST 27.

MONDAY, AUGUST 30.

TUESDAY, AUGUST 31.

SECTION D.—ZOOLOGY.

THURSDAY, AUGUST 26.

FRIDAY, AUGUST 27.

FRIDAY, AUGUST 27.

MONDAY, AUGUST 30.

TUESDAY, AUGUST 31.

WEDNESDAY, SEPTEMBER 1.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

THURSDAY, AUGUST 26.

FRIDAY, AUGUST 27.

MONDAY, AUGUST 30.

TUESDAY, AUGUST 31.

SECTION G.—ENGINEERING.

THURSDAY, AUGUST 26.

FRIDAY, AUGUST 27.

MONDAY, AUGUST 30.

TUESDAY, AUGUST 31.

WEDNESDAY, SEPTEMBER 1.

SECTION H.—ANTHROPOLOGY.

THURSDAY, AUGUST 26.

FRIDAY, AUGUST 27.

Section I.—PHYSIOLOGY.

THURSDAY, AUGUST 26.

FRIDAY, AUGUST 27.

MONDAY, AUGUST 30.

TUESDAY, AUGUST 31.

WEDNESDAY, SEPTEMBER 1.

Section K.—BOTANY.

THURSDAY, AUGUST 26.

FRIDAY, AUGUST 27.

FRIDAY, AUGUST 27.

MONDAY, AUGUST 30.

TUESDAY, AUGUST 31.

SECTION L.—EDUCATIONAL SCIENCE.

THURSDAY, AUGUST 26.

FRIDAY, AUGUST 27.

MONDAY, AUGUST 30.

TUESDAY, AUGUST 31.

EVENING DISCOURSES.

THURSDAY, AUGUST 26.

TUESDAY, AUGUST 31.

APPENDIX A.

PAPERS READ AT THE DISCUSSION ON WHEAT.

APPENDIX B.

LIST OF PLATES.

OFFICERS AND COUNCIL, 1909–1910.

PATRON.

HIS MAJESTY THE KING.

PRESIDENT.

PROFESSOR SIR J. J. THOMSON, M.A., LL.D., D.SC., F.R.S.

VICE-PRESIDENTS.

The Right Hon. LORD STRATHCONA AND MOUNT ROYAL, G.C.M.G., G.C.V.O., LL.D., High Commissioner in London for the Dominion of Canada.
The Right Hon. Sir WILFRID LAURIER, G.C.M.G., P.C., D.L., Prime Minister and President of Privy Council.
The Hon. Sir DANIEL HUNTER MCMILLAN, K.C.M.G., Lieutenant-Governor of Manitoba.
The Hon. RODMOND PALEN ROBLIN, Premier of Manitoba.
The Hon. AMEDEE E. FORGET, Lieutenant-Governor of Saskatchewan.
The Hon. WALTER SCOTT, Premier of Saskatchewan.
The Hon. GEORGE H. V. BULYEA, Lieutenant-Governor of Alberta.
The Hon. ALEX. C. RUTHERFORD, B.A., LL.D., Premier of Alberta.
The Hon. JAMES DUNSMUIR, Lieutenant-Governor of British Columbia.
The Hon. RICHARD MCBRIDE, LL.B., K.C., Premier of British Columbia.

PRESIDENT ELECT.

Rev. Professor T. G. BONNEY, Sc.D., LL.D., F.R.S.

VICE-PRESIDENTS ELECT.

The Right Hon. the Lord Mayor of Sheffield, The EARL FITZWILLIAM, D.S.O.
The Master Cutler of Sheffield, HERBERT BARBER.
His Grace the LORD ARCHBISHOP OF YORK.
His Grace the DUKE OF NORFOLK, E.M., K.G., G.C.V.O., Litt.D., Chancellor of Sheffield University.
The Right Hon. the EARL OF HAREWOOD, K.C.V.O., Lord-Lieutenant of the West Riding of Yorkshire.
Alderman GEORGE FRANKLIN, Litt.D., Pro-Chancellor of Sheffield University.
Sir CHARLES ELIOT, K.C.M.G., C.B., Vice-Chancellor of Sheffield University.
Alderman H. K. STEPHENSON, Deputy Lord Mayor of Sheffield
The Right Rev. J. N. QUIRK, D.D., Lord Bishop of Sheffield.
A. J. HOBSON, President of the Sheffield Chamber of Commerce.
Alderman Sir WILLIAM CLEGG, J.P., Chairman of the Sheffield Education Committee.
Colonel HERBERT HUGHES, C.M.G.
Professor W. M. HICKS, Sc.D., F.R.S.
Rev. E. H. TITCHMARSH, M.A., President of the Sheffield Free Church Council.

GENERAL TREASURER.

Professor JOHN PERRY, D.Sc., LL.D., F.R.S.

GENERAL SECRETARIES.

Major P. A. MACMAHON, R.A., D.Sc., F.R.S. | Professor W. A. HERDMAN, D.Sc., F.R.S.

ASSISTANT SECRETARY.

O. J. R. HOWARTH, M.A., Burlington House, London, W.

CHIEF CLERK AND ASSISTANT TREASURER.

H. C. STEWARDSON, Burlington House, London, W.

LOCAL TREASURER FOR THE MEETING AT SHEFFIELD.

Alderman H. K. STEPHENSON.

LOCAL SECRETARIES FOR THE MEETING AT SHEFFIELD.

R. M. PRESCOTT. | W. M. GIBBONS, M.A.

[P.T.O.

ORDINARY MEMBERS OF THE COUNCIL.

ABNEY, Sir W., K.C.B., F.R.S.
ANDERSON, TEMPEST, M.D., D.Sc.
ARMSTRONG, Professor H. E., F.R.S.
BERKELEY, Rt. Hon. the EARL OF, F.R.S.
BOWLEY, A. L., M.A.
BRABROOK, Sir EDWARD, C.B.
BROWN, Dr. HORACE T., F.R.S.
BRUNTON, Sir LAUDER, Bart., F.R.S.
CLOSE, Colonel C. F., R.E., C.M.G.
CRAIGIE, Major P. G., C.B.
DYSON, Professor F. W., F.R.S.
GLAZEBROOK, Dr. R. T., F.R.S.
HALL, A. D., F.R.S.
HARTLAND, E. SIDNEY, F.S.A.
HOGARTH, D. G., M.A.
MITCHELL, Dr. P. CHALMERS, F.R.S.
MYRES, Professor J. L., M.A.
POULTON, Professor E. B., F.R.S.
PRAIN, Lieut.-Colonel D., C.I.E., F.R.S.
SHERRINGTON, Professor C. S., F.R.S.
SHIPLEY, Dr. A. E., F.R.S.
TEALL, J. J. H., F.R.S.
TUTTON, Dr. A. E. H., F.R.S.
WOLFE-BARRY, Sir JOHN, K.C.B., F.R.S.
WOODWARD, Dr. A. SMITH, F.R.S.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past-Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

TRUSTEES (PERMANENT).

The Right Hon. Lord AVEBURY, D.C.L., LL.D., F.R.S., F.L.S.
The Right Hon. Lord RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S.
Sir ARTHUR W. RÜCKER, M.A., D.Sc., LL.D., F.R.S.

PAST PRESIDENTS OF THE ASSOCIATION.

Sir Joseph D. Hooker, G.C.S.I.
Lord Avebury, D.C.L., F.R.S.
Lord Rayleigh, D.C.L., F.R.S.
Sir H. E. Roscoe, D.C.L., F.R.S.
Sir William Huggins, K.C.B., F.R.S.
Sir A. Geikie, K.C.B., Pres. R.S.
Lord Lister, D.C.L., F.R.S.
Sir William Crookes, F.R.S.
Sir W. Turner, K.C.B., F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.
Sir James Dewar, LL.D., F.R.S.
Sir Norman Lockyer, K.C.B., F.R.S.
Arthur J. Balfour, D.C.L., F.R.S.
Sir George Darwin, K.C.B., F.R.S.
Sir E. Ray Lankester, K.C.B., F.R.S.
Sir David Gill, K.C.B., F.R.S.
Dr. Francis Darwin, F.R.S.

PAST GENERAL OFFICERS OF THE ASSOCIATION.

Sir F. Galton, D.C.L., F.R.S.
P. L. Sclater, Ph.D., F.R.S.
Prof. T. G. Bonney, Sc.D., F.R.S.
A. Vernon Harcourt, F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.
Prof. E. A. Schäfer, F.R.S.
Dr. D. H. Scott, M.A., F.R.S.
Dr. G. Carey Foster, F.R.S.
Dr. J. G. Garson.

AUDITORS.

Sir Edward Brabrook, C.B.
Professor H. McLeod, F.R.S.

RULES OF
THE BRITISH ASSOCIATION.

[*Adopted by the General Committee at Leicester*, 1907.]

CHAPTER I.

Objects and Constitution.

1. The objects of the British Association for the Advancement of Science are: To give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of those who cultivate Science in different parts of the British Empire with one another and with foreign philosophers; to obtain more general attention for the objects of Science and the removal of any disadvantages of a public kind which impede its progress. Objects.

The Association contemplates no invasion of the ground occupied by other Institutions.

2. The Association shall consist of Members, Associates, and Honorary Corresponding Members. Constitution.

The governing body of the Association shall be a General Committee, constituted as hereinafter set forth; and its affairs shall be directed by a Council and conducted by General Officers appointed by that Committee.

3. The Association shall meet annually, for one week or longer, and at such other times as the General Committee may appoint. The place of each Annual Meeting shall be determined by the General Committee not less than two years in advance; and the arrangements for these meetings shall be entrusted to the Officers of the Association. Annual Meetings.

CHAPTER II.

The General Committee.

1. The General Committee shall be constituted of the following persons: Constitution.

(i) *Permanent Members*—

(*a*) Past and present Members of the Council, and past and present Presidents of the Sections.

(*b*) Members who, by the publication of works or papers, have furthered the advancement of knowledge in any of those departments which are assigned to the Sections of the Association.

(ii) *Temporary Members*—

(*a*) Vice-Presidents and Secretaries of the Sections.
(*b*) Honorary Corresponding Members, foreign representatives, and other persons specially invited or nominated by the Council or General Officers.
(*c*) Delegates nominated by the Affiliated Societies.
(*d*) Delegates—not exceeding altogether three in number—from Scientific Institutions established at the place of meeting.

Admission. 2. The decision of the Council on the qualifications and claims of any Member of the Association to be placed on the General Committee shall be final.

(i) Claims for admission as a Permanent Member must be lodged with the Assistant Secretary at least one month before the Annual Meeting.
(ii) Claims for admission as a Temporary Member may be sent to the Assistant Secretary at any time before or during the Annual Meeting.

Meetings. 3. The General Committee shall meet twice at least during every Annual Meeting. In the interval between two Annual Meetings, it shall be competent for the Council at any time to summon a meeting of the General Committee.

Functions. 4. The General Committee shall

(i) Receive and consider the report of the Council.
(ii) Elect a Committee of Recommendations.
(iii) Receive and consider the report of the Committee of Recommendations.
(iv) Determine the place of the Annual Meeting not less than two years in advance.
(v) Determine the date of the next Annual Meeting.
(vi) Elect the President and Vice-Presidents, Local Treasurer and Local Secretaries for the next Annual Meeting.
(vii) Elect Ordinary Members of Council.
(viii) Appoint General Officers.
(ix) Appoint Auditors.
(x) Elect the officers of the Conference of Delegates.
(xi) Receive any notice of motion for the next Annual Meeting.

Chapter III.

Committee of Recommendations.

1. * The *ex officio* Members of the Committee of Recommendations are the President and Vice-Presidents of the Association, the President of each Section at the Annual Meeting, the Chairman of the Conference of Delegates, the General Secretaries, the General Treasurer, the Trustees, and the Presidents of the Association in former years. Constitution.

An Ordinary Member of the Committee for each Section shall be nominated by the Committee of that Section.

If the President of a Section be unable to attend a meeting of the Committee of Recommendations, the Sectional Committee may appoint a Vice-President, or some other member of the Committee, to attend in his place, due notice of such appointment being sent to the Assistant Secretary.

2. Every recommendation made under Chapter IV. and every resolution on a scientific subject, which may be submitted to the Association by any Sectional Committee, or by the Conference of Delegates, or otherwise than by the Council of the Association, shall be submitted to the Committee of Recommendations. If the Committee of Recommendations approve such recommendation, they shall transmit it to the General Committee; and no recommendation shall be considered by the General Committee that is not so transmitted. Functions.

Every recommendation adopted by the General Committee shall, if it involve action on the part of the Association, be transmitted to the Council; and the Council shall take such action as may be needful to give effect to it, and shall report to the General Committee not later than the next Annual Meeting.

Every proposal for establishing a new Section or Sub-Section, for altering the title of a Section, or for any other change in the constitutional forms or fundamental rules of the Association, shall be referred to the Committee of Recommendations for their consideration and report.

3. The Committee of Recommendations shall assemble, for the despatch of business, on the Monday of the Annual Meeting, and, if necessary, on the following day. Their Report must be submitted to the General Committee on the last day of the Annual Meeting. Procedure.

* Amended by the General Committee at Winnipeg, 1909.

CHAPTER IV.

Research Committees.

Procedure.

1. Every proposal for special research, or for a grant of money in aid of special research, which is made in any Section, shall be considered by the Committee of that Section; and, if such proposal be approved, it shall be referred to the Committee of Recommendations.

In consequence of any such proposal, a Sectional Committee may recommend the appointment of a Research Committee, composed of Members of the Association, to conduct research or administer a grant in aid of research, and in any case to report thereon to the Association; and the Committee of Recommendations may include such recommendation in their report to the General Committee.

Constitution.

2. Every appointment of a Research Committee shall be proposed at a meeting of the Sectional Committee and adopted at a subsequent meeting. The Sectional Committee shall settle the terms of reference and suitable Members to serve on it, which must be as small as is consistent with its efficient working; and shall nominate a Chairman and a Secretary. Such Research Committee, if appointed, shall have power to add to their numbers.

Proposals by Sectional Committees.

3. The Sectional Committee shall state in their recommendation whether a grant of money be desired for the purposes of any Research Committee, and shall estimate the amount required.

All proposals sanctioned by a Sectional Committee shall be forwarded by the Recorder to the Assistant Secretary not later than noon on the Monday of the Annual Meeting for presentation to the Committee of Recommendations.

Tenure.

4. Research Committees are appointed for one year only. If the work of a Research Committee cannot be completed in that year, application may be made through a Sectional Committee at the next Annual Meeting for reappointment, with or without a grant—or a further grant—of money.

Reports.

5. Every Research Committee shall present a Report, whether interim or final, at the Annual Meeting next after that at which it was appointed or reappointed. Interim Reports, whether intended for publication or not, must be submitted in writing. Each Sectional Committee shall ascertain whether a Report has been made by each Research Committee

appointed on their recommendation, and shall report to the Committee of Recommendations on or before the Monday of the Annual Meeting.

6. In each Research Committee to which a grant of money has been made, the Chairman is the only person entitled to call on the General Treasurer for such portion of the sum granted as from time to time may be required. GRANTS. (*a*) Drawn by Chairman.

Grants of money sanctioned at the Annual Meeting expire on June 30 following. The General Treasurer is not authorised, after that date, to allow any claims on account of such grants. (*b*) Expire on June 30.

The Chairman of a Research Committee must, before the Annual Meeting next following the appointment of the Research Committee, forward to the General Treasurer a statement of the sums that have been received and expended, together with vouchers. The Chairman must then either return the balance of the grant, if any, which remains unexpended, or, if further expenditure be contemplated, apply for leave to retain the balance. (*c*) Accounts, and balance in hand.

When application is made for a Committee to be reappointed, and to retain the balance of a former grant, and also to receive a further grant, the amount of such further grant is to be estimated as being sufficient, together with the balance proposed to be retained, to make up the amount desired. (*d*) Additional Grants

In making grants of money to Research Committees, the Association does not contemplate the payment of personal expenses to the Members. (*e*) *Caveat.*

A Research Committee, whether or not in receipt of a grant, shall not raise money, in the name or under the auspices of the Association, without special permission from the General Committee.

7. Members and Committees entrusted with sums of money for collecting specimens of any description shall include in their Reports particulars thereof, and shall reserve the specimens thus obtained for disposal, as the Council may direct. Disposal of specimens, apparatus, &c.

Committees are required to furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and to state whether the apparatus is likely to be useful for continuing the research in question or for other specific purposes.

All instruments, drawings, papers, and other property of the Association, when not in actual use by a Committee, shall be deposited at the Office of the Association.

Chapter V.

The Council.

Constitution. 1. The Council shall consist of *ex officio* Members and of Ordinary Members elected annually by the General Committee.

(i) The *ex officio* Members are—the Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

(ii) The Ordinary Members shall not exceed twenty-five in number. Of these, not more than twenty shall have served on the Council as Ordinary Members in the previous year.

Functions. 2. The Council shall have authority to act, in the name and on behalf of the Association, in all matters which do not conflict with the functions of the General Committee.

In the interval between two Annual Meetings, the Council shall manage the affairs of the Association and may fill up vacancies among the General and other Officers, until the next Annual Meeting.

The Council shall hold such meetings as they may think fit, and shall in any case meet on the first day of the Annual Meeting, in order to complete and adopt the Annual Report, and to consider other matters to be brought before the General Committee.

The Council shall nominate for election by the General Committee, at each Annual Meeting, a President and General Officers of the Association.

Suggestions for the Presidency shall be considered by the Council at the Meeting in February, and the names selected shall be issued with the summonses to the Council Meeting in March, when the nomination shall be made from the names on the list.

The Council shall have power to appoint and dismiss such paid officers as may be necessary to carry on the work of the Association, on such terms as they may from time to time determine.

3. Election to the Council shall take place at the same time as that of the Officers of the Association. Elections.

(i) At each Annual Election, the following Ordinary Members of the Council shall be ineligible for re-election in the ensuing year:

(*a*) Three of the Members who have served for the longest consecutive period, and

(*b*) Two of the Members who, being resident in or near London, have attended the least number of meetings during the past year.

Nevertheless, it shall be competent for the Council, by an unanimous vote, to reverse the proportion in the order of retirement above set forth.

(ii) The Council shall submit to the General Committee, in their Annual Report, the names of twenty-three Members of the Association whom they recommend for election as Members of Council.

(iii) Two Members shall be elected by the General Committee, without nomination by the Council; and this election shall be at the same meeting as that at which the election of the other Members of the Council takes place.

Any member of the General Committee may propose another member thereof for election as one of these two members of Council, and, if only two are so proposed, they shall be declared elected; but, if more than two are so proposed, the election shall be by show of hands, unless five members at least require it to be by ballot.

Chapter VI.

The President, General Officers, and Staff.

1. The President assumes office on the first day of the Annual Meeting, when he delivers a Presidential Address. He resigns office at the next Annual Meeting, when he inducts his successor into the Chair. The President.

The President shall preside at all meetings of the Association or of its Council and Committees which he attends in his capacity as President. In his absence, he shall be represented by a Vice-President or past President of the Association.

2. The General Officers of the Association are the General Treasurer and the General Secretaries. General Officers.

It shall be competent for the General Officers to act, in the name of the Association, in any matter of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next meeting.

The General Treasurer.

3. The General Treasurer shall be responsible to the General Committee and the Council for the financial affairs of the Association.

The General Secretaries.

4. The General Secretaries shall control the general organisation and administration, and shall be responsible to the General Committee and the Council for conducting the correspondence and for the general routine of the work of the Association, excepting that which relates to Finance.

The Assistant Secretary.

5. The Assistant Secretary shall hold office during the pleasure of the Council. He shall act under the direction of the General Secretaries, and in their absence shall represent them. He shall also act on the directions which may be given him by the General Treasurer in that part of his duties which relates to the finances of the Association.

The Assistant Secretary shall be charged, subject as aforesaid: (i) with the general organising and editorial work, and with the administrative business of the Association; (ii) with the control and direction of the Office and of all persons therein employed; and (iii) with the execution of Standing Orders or of the directions given him by the General Officers and Council. He shall act as Secretary, and take Minutes, at the meetings of the Council, and at all meetings of Committees of the Council, of the Committee of Recommendations, and of the General Committee.

Assistant Treasurer.

6. The General Treasurer may depute one of the Staff, as Assistant Treasurer, to carry on, under his direction, the routine work of the duties of his office.

The Assistant Treasurer shall be charged with the issue of Membership Tickets, the payment of Grants, and such other work as may be delegated to him.

Chapter VII.

Finance.

Financial Statements.

1. The General Treasurer, or Assistant Treasurer, shall receive and acknowledge all sums of money paid to the Association. He shall submit, at each meeting of the Council, an *interim* statement of his Account; and, after

June 30 in each year, he shall prepare and submit to the General Committee a balance-sheet of the Funds of the Association.

2. The Accounts of the Association shall be audited, annually, by Auditors appointed by the General Committee. Audit.

3. The General Treasurer shall make all ordinary payments authorised by the General Committee or by the Council. Expenditure.

4. The General Treasurer is empowered to draw on the account of the Association, and to invest on its behalf, part or all of the balance standing at any time to the credit of the Association in the books of the Bank of England, either in Exchequer Bills or in any other temporary investment, and to change, sell, or otherwise deal with such temporary investment as may seem to him desirable. Investments.

5. In the event of the General Treasurer being unable, from illness or any other cause, to exercise the functions of his office, the President of the Association for the time being and one of the General Secretaries shall be jointly empowered to sign cheques on behalf of the Association. Cheques.

Chapter VIII.

The Annual Meetings.

1. Local Committees shall be formed to assist the General Officers in making arrangements for the Annual Meeting, and shall have power to add to their number. Local Officers and Committees.

2. The General Committee shall appoint, on the recommendation of the Local Reception or Executive Committee for the ensuing Annual Meeting, a Local Treasurer or Treasurers and two or more Local Secretaries, who shall rank as officers of the Association, and shall consult with the General Officers and the Assistant Secretary as to the local arrangements necessary for the conduct of the meeting. The Local Treasurers shall be empowered to enrol Members and Associates, and to receive subscriptions.

3. The Local Committees and Sub-Committees shall undertake the local organisation, and shall have power to act in the name of the Association in all matters pertaining to the local arrangements for the Annual Meeting other than the work of the Sections. Functions.

Chapter IX.

The Work of the Sections.

The Sections.

1. The scientific work of the Association shall be transacted under such Sections as shall be constituted from time to time by the General Committee.

It shall be competent for any Section, if authorised by the Council for the time being, to form a Sub-Section for the purpose of dealing separately with any group of communications addressed to that Section.

Sectional Officers.

2. There shall be in each Section a President, two or more Vice-Presidents, and two or more Secretaries. They shall be appointed by the Council, for each Annual Meeting in advance, and shall act as the Officers of the Section from the date of their appointment until the appointment of their successors in office for the ensuing Annual Meeting.

Of the Secretaries, one shall act as Recorder of the Section, and one shall be resident in the locality where the Annual Meeting is held.

Rooms.

3. The Section Rooms and the approaches thereto shall not be used for any notices, exhibitions, or other purposes than those of the Association.

Sectional Committees.

4. The work of each Section shall be conducted by a Sectional Committee, which shall consist of the following :—

Constitution.

(i) The Officers of the Section during their term of office.
(ii) All past Presidents of that Section.
(iii) Such other Members of the Association, present at any Annual Meeting, as the Sectional Committee, thus constituted, may co-opt for the period of the meeting :

Provided always that—

Privilege of Old Members.

(*a*) Any Member of the Association who has served on the Committee of any Section in any previous year, and who has intimated his intention of being present at the Annual Meeting, is eligible as a member of that Committee at their first meeting.

Daily Co-optation.

(*b*) A Sectional Committee may co-opt members, as above set forth, at any time during the Annual Meeting, and shall publish daily a revised list of the members.

(c) A Sectional Committee may, at any time during the Annual Meeting, appoint not more than three persons present at the meeting to be Vice-Presidents of the Section, in addition to those previously appointed by the Council. Additional Vice-Presidents.

5. The chief executive officers of a Section shall be the President and the Recorder. They shall have power to act on behalf of the Section in any matter of urgency which cannot be brought before the consideration of the Sectional Committee; and they shall report such action to the Sectional Committee at its next meeting. EXECUTIVE FUNCTIONS

The President (or, in his absence, one of the Vice-Presidents) shall preside at all meetings of the Sectional Committee or of the Section. His ruling shall be absolute on all points of order that may arise. Of President

The Recorder shall be responsible for the punctual transmission to the Assistant Secretary of the daily programme of his Section, of the recommendations adopted by the Sectional Committee, of the printed returns, abstracts, reports, or papers appertaining to the proceedings of his Section at the Annual Meeting, and for the correspondence and minutes of the Sectional Committee. And of Recorder.

6. The Sectional Committee shall nominate, before the close of the Annual Meeting, not more than six of its own members to be members of an Organising Committee, with the officers to be subsequently appointed by the Council, and past Presidents of the Section, from the close of the Annual Meeting until the conclusion of its meeting on the first day of the ensuing Annual Meeting. Organising Committee.

Each Organising Committee shall hold such Meetings as are deemed necessary by its President for the organisation of the ensuing Sectional proceedings, and shall hold a meeting on the first Wednesday of the Annual Meeting: to nominate members of the Sectional Committee, to confirm the Provisional Programme of the Section, and to report to the Sectional Committee.

Each Sectional Committee shall meet daily, unless otherwise determined, during the Annual Meeting: to co-opt members, to complete the arrangements for the next day, and to take into consideration any suggestion for the advancement of Science that may be offered by a member, or may arise out of the proceedings of the Section. Sectional Committee.

No paper shall be read in any Section until it has been accepted by the Sectional Committee and entered as accepted on its Minutes. Papers and Reports.

Any report or paper read in any one Section may be read also in any other Section.

No paper or abstract of a paper shall be printed in the Annual Report of the Association unless the manuscript has been received by the Recorder of the Section before the close of the Annual Meeting.

Recommendations.

It shall be within the competence of the Sectional Committee to review the recommendations adopted at preceding Annual Meetings, as published in the Annual Reports of the Association, and the communications made to the Section at its current meetings, for the purpose of selecting definite objects of research, in the promotion of which individual or concerted action may be usefully employed ; and, further, to take into consideration those branches or aspects of knowledge on the state and progress of which reports are required : to make recommendations and nominate individuals or Research Committees to whom the preparation of such reports, or the task of research, may be entrusted, discriminating as to whether, and in what respects, these objects may be usefully advanced by the appropriation of money from the funds of the Association, whether by reference to local authorities, public institutions, or Departments of His Majesty's Government. The appointment of such Research Committees shall be made in accordance with the provisions of Chapter IV.

No proposal arising out of the proceedings of any Section shall be referred to the Committee of Recommendations unless it shall have received the sanction of the Sectional Committee.

Publication.

7. Papers ordered to be printed *in extenso* shall not be included in the Annual Report, if published elsewhere prior to the issue of the Annual Report in volume form. Reports of Research Committees shall not be published elsewhere than in the Annual Report without the express sanction of the Council.

Copyright.

8. The copyright of papers ordered by the General Committee to be printed *in extenso* in the Annual Report shall be vested in the authors ; and the copyright of the reports of Research Committees appointed by the General Committee shall be vested in the Association.

Chapter X.

Admission of Members and Associates.

1. No technical qualification shall be required on the part of an applicant for admission as a Member or as an Associate of the British Association; but the Council is empowered, in the event of special circumstances arising, to impose suitable conditions and restrictions in this respect. Applications.

* Every person admitted as a Member or an Associate shall conform to the Rules and Regulations of the Association, any infringement of which on his part may render him liable to exclusion by the Council, who have also authority, if they think it necessary, to withhold from any person the privilege of attending any Annual Meeting or to cancel a ticket of admission already issued. Obligations.

It shall be competent for the General Officers to act, in the name of the Council, on any occasion of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next Meeting.

2. All Members are eligible to any office in the Association. Conditions and Privileges of Membership.

(i) Every *Life Member* shall pay, on admission, the sum of Ten Pounds.

Life Members shall receive *gratis* the Annual Reports of the Association.

(ii) Every *Annual Member* shall pay, on admission, the sum of Two Pounds, and in any subsequent year the sum of One Pound.

Annual Members shall receive *gratis* the Report of the Association for the year of their admission and for the years in which they continue to pay, *without intermission*, their annual subscription. An Annual Member who omits to subscribe for any particular year shall lose for that and all future years the privilege of receiving the Annual Reports of the Association *gratis*. He, however, may resume his other privileges as a Member at any subsequent Annual Meeting by paying on each such occasion the sum of One Pound.

(iii) Every *Associate* for a year shall pay, on admission, the sum of One Pound.

* Amended by the General Committee at Dublin 1908.

Associates shall not receive the Annual Report gratuitously. They shall not be eligible to serve on any Committee, nor be qualified to hold any office in the Association.

(iv) *Ladies* may become Members or Associates on the same terms as gentlemen, or can obtain a *Lady's Ticket* (transferable to ladies only) on the payment of One Pound.

Corresponding Members.

3. Corresponding Members may be appointed by the General Committee, on the nomination of the Council. They shall be entitled to all the privileges of Membership.

Annual Subscriptions.

4. Subscriptions are payable at or before the Annual Meeting. Annual Members not attending the meeting may make payment at any time before the close of the financial year on June 30 of the following year.

The Annual Report.

5. The Annual Report of the Association shall be forwarded *gratis* to individuals and institutions entitled to receive it.

Annual Members whose subscriptions have been intermitted shall be entitled to purchase the Annual Report at two-thirds of the publication price; and Associates for a year shall be entitled to purchase, at the same price, the volume for that year.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Chapter XI.

Corresponding Societies: Conference of Delegates.

Corresponding Societies are constituted as follows:

Affiliated Societies.

1. (i) Any Society which undertakes local scientific investigation and publishes the results may become a Society *affiliated* to the British Association.

Each Affiliated Society may appoint a Delegate, who must be or become a Member of the Association and must attend the meetings of the Conference of Delegates. He shall be *ex officio* a Member of the General Committee.

Associated Societies.

(ii) Any Society formed for the purpose of encouraging the study of Science, which has existed for three years and numbers not fewer than fifty members, may become a Society *associated* with the British Association.

Each Associated Society shall have the right to appoint a Delegate to attend the Annual Conference. Such Delegates must be or become either Members or Associates of the British Association, and shall have all the rights of Delegates appointed by the Affiliated Societies, except that of membership of the General Committee.

Applications.

2. Application may be made by any Society to be placed on the list of Corresponding Societies. Such application must be addressed to the Assistant Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended it should be considered, and must, in the case of Societies desiring to be affiliated, be accompanied by specimens of the publications of the results of local scientific investigations recently undertaken by the Society.

CORRESPONDING SOCIETIES COMMITTEE.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee, for the purpose of keeping themselves generally informed of the work of the Corresponding Societies and of superintending the preparation of a list of the papers published by the Affiliated Societies. This Committee shall make an Annual Report to the Council, and shall suggest such additions or changes in the list of Corresponding Societies as they may consider desirable.

Procedure.

(i) Each Corresponding Society shall forward every year to the Assistant Secretary of the Association, on or before June 1, such particulars in regard to the Society as may be required for the information of the Corresponding Societies Committee.

(ii) There shall be inserted in the Annual Report of the Association a list of the papers published by the Corresponding Societies during the preceding twelve months which contain the results of local scientific work conducted by them—those papers only being included which refer to subjects coming under the cognisance of one or other of the several Sections of the Association.

CONFERENCE OF DELEGATES.

4. The Delegates of Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairman, and Secretary or Secretaries shall be nominated annually by the Council and appointed by the General Committee. The members of the Corresponding Societies Committee shall be *ex officio* members of the Conference.

Procedure and Functions.

(i) The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during

each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the discussions.

(ii) The Conference of Delegates shall be empowered to submit Resolutions to the Committee of Recommendations for their consideration, and for report to the General Committee.

(iii) The Sectional Committees of the Association shall be requested to transmit to the Secretaries of the Conference of Delegates copies of any recommendations to be made to the General Committee bearing on matters in which the co-operation of Corresponding Societies is desirable. It shall be competent for the Secretaries of the Conference of Delegates to invite the authors of such recommendations to attend the meetings of the Conference in order to give verbal explanations of their objects and of the precise way in which they desire these to be carried into effect.

(iv) It shall be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they may be able to bring such recommendations adequately before their respective Societies.

(v) The Conference may also discuss propositions regarding the promotion of more systematic observation and plans of operation, and of greater uniformity in the method of publishing results.

Chapter XII.

Amendments and New Rules.

Alterations. Any alterations in the Rules, and any amendments or new Rules that may be proposed by the Council or individual Members, shall be notified to the General Committee on the first day of the Annual Meeting, and referred forthwith to the Committee of Recommendations; and, on the report of that Committee, shall be submitted for approval at the last meeting of the General Committee.

Table showing the Places and Dates of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Foundation.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
VISCOUNT MILTON, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S., F.R.S.E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S., F.R.S.E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S., F.R.S.E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astronomer Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London. LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. The Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.

The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S., F.R.S.E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S., F.R.S.E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S., F.R.S.E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.

PRESIDENTS.	VICE-PRESIDENTS	LOCAL SECRETARIES.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S., F.R.S.E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S., F.R.S.E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.

WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E. Joseph Whitworth, Esq., F.R.S., M.Inst.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford. BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hind, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S., F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.

PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S., F.R.S.E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S., F.R.S.E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Right Hon. the Earl of Chichester, Lord-Lieutenant of the County of Sussex. His Grace the Duke of Norfolk His Grace the Duke of Richmond, K.G., P.C., D.C.L. His Grace the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. The Right Hon. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Sir John Hawkshaw, F.R.S., F.G.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, M.Inst.C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S., F.R.S.E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S., F.R.S.E. Professor Allen Thomson, M.D., LL.D., F.R.S., F.R.S.E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S., F.R.S.E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom and of the Museum of Practical Geology SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S., F.R.S.E. Professor Allman, M.D., LL.D., F.R.S.L., F.R.S.E., F.L.S	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc.
C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	The Right Hon. the Lord Mount-Temple Captain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.

ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.
The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D. The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., LL.D., F.R.S. L. & E. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. The Hon. Sir Charles Tupper, K.C.M.G. Chief Justice Sir A. A. Dorion, C.M.G. Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. The Hon. Dr. Chauveau Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S. W. H. Hingston, Esq., M.D., D.C.L., L.R.C.S.E. Thomas Sterry Hunt, Esq., M.A., D.Sc., LL.D., F.R.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.
The RIGHT HON. SIR LYON PLAYFAIR, K.C.B., M.P., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. ABERDEEN, September 9, 1885.	His Grace the Duke of Richmond and Gordon, K.C., D.C.L., Chancellor of the University of Aberdeen The Right Hon. the Earl of Aberdeen, LL.D., Lord-Lieutenant of Aberdeenshire The Right Hon. the Earl of Crawford and Balcarres, M.A., LL.D., F.R.S., F.R.A.S. James Matthews, Esq., Lord Provost of the City of Aberdeen Professor Sir William Thomson, M.A., LL.D., F.R.S., F.R.S.E., F.R.A.S. Alexander Bain, Esq., M.A., LL.D., Rector of the University of Aberdeen The Very Rev. Principal Pirie, D.D., Vice-Chancellor of the University of Aberdeen Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres. Z.S., F.G.S., Director of the Natural History Museum, London Professor John Struthers, M.D., LL.D.	J. W. Crombie, Esq., M.A. Angus Fraser, Esq., M.A., M.D., F.C.S. Professor G. Pirie, M.A.
SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of McGill University, Montreal, Canada BIRMINGHAM, September 1, 1886.	The Right Hon. the Earl of Bradford, Lord-Lieutenant of Shropshire. The Right Hon. Lord Leigh, D.C.L., Lord-Lieutenant of Warwickshire. The Right Hon. Lord Norton, K.C.M.G. The Right Hon. Lord Wrottesley, Lord-Lieutenant of Staffordshire The Right Rev. the Lord Bishop of Worcester, D.D. Thomas Martineau, Esq., Mayor of Birmingham Professor G. G. Stokes, M.A., D.C.L., LL.D., Pres. R.S. Professor W. A. Tilden, D.Sc., F.R.S., F.C.S. Rev. A. R. Vardy, M.A. Rev. H. W. Watson, D.Sc., F.R.S.	J. Barham Carslake, Esq. Rev. H. W. Crosskey, LL.D., F.G.S. Charles J. Hart, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR H. E. ROSCOE, M.P., D.C.L., LL.D., Ph.D., F.R.S., V.P.C.S. MANCHESTER, August 31, 1887.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Right Hon. the Earl of Derby, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Rev. the Lord Bishop of Manchester, D.D. The Right Rev. the Bishop of Salford The Right Worshipful the Mayor of Manchester The Right Worshipful the Mayor of Salford The Vice-Chancellor of the Victoria University The Principal of the Owens College Sir William Roberts, B.A., M.D., F.R.S. Thomas Ashton, Esq., J.P., D.L. Oliver Heywood, Esq., J.P., D.L. James Prescott Joule, Esq., D.C.L., LL.D., F.R.S., F.R.S.E., F.C.S.	F. J. Faraday, Esq., F.L.S., F.S.S. Charles Hopkinson, Esq., B.Sc. Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S. Professor A. H. Young, M.B., F.R.C.S.
SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.Inst.C.E. BATH, September 5, 1888.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somerset The Most Hon. the Marquess of Bath The Right Hon. and Right Rev. the Lord Bishop of Bath and Wells, D.D. The Right Rev. the Bishop of Clifton, D.D. The Right Worshipful the Mayor of Bath The Right Worshipful the Mayor of Bristol Sir F. A. Abel, C.B., D.C.L., F.R.S., V.P.C.S. The Venerable the Archdeacon of Bath, M.A. The Rev. Leonard Blomefield, M.A., F.L.S., F.G.S. Professor Michael Foster, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S. W. S. Gore-Langton, Esq., J.P., D.L. H. D. Skrine, Esq., J.P., D.L. E. R. Wodehouse, Esq., M.P. Colonel R. P. Laurie, C.B., M.P. Jerom Murch, Esq., J.P., D.L.	W. Pumphrey, Esq. J. L. Stothert, Esq., M.Inst.C.E. B. H. Watts, Esq.
PROFESSOR WILLIAM HENRY FLOWER, C.B., LL.D., F.R.S., F.R.C.S., Pres. Z.S., F.L.S., F.G.S., Director of the Natural History Departments of the British Museum NEWCASTLE-UPON-TYNE, September 11, 1889.	His Grace the Duke of Northumberland, K.G., D.C.L., LL.D., Lord-Lieutenant of Northumberland The Right Hon. the Earl of Durham, Lord-Lieutenant of Durham The Right Hon. the Earl of Ravensworth The Right Rev. the Lord Bishop of Newcastle, D.D. The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S. The Right Hon. John Morley, M.P., LL.D. The Very Rev. the Warden of the University of Durham, D.D. The Right Worshipful the Mayor of Newcastle The Worshipful the Mayor of Gateshead Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S., M.Inst.C.E. Sir Charles Mark Palmer, Bart., M.P.	Professor P. Phillips Bedson, D.Sc., F.C.S. Professor J. Herman Merivale, M.A.

SIR FREDERICK AUGUSTUS ABEL, C.B., D.C.L., D.Sc., F.R.S., F.C.S., Hon.M.Inst.C.E. LEEDS, September 3, 1890.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S. The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., F.R.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Sir Lyon Playfair, K.C.B., Ph.D., LL.D., M.P., F.R.S. The Right Hon. W. L. Jackson, M.P. Sir James Kitson, Bart., M.Inst.C.E. The Mayor of Leeds Sir Andrew Fairbairn, M.A.	J. Rawlinson Ford, Esq. Sydney Lupton, Esq., M.A. Professor L. C. Miall, F.L.S., F.G.S. Professor A. Smithells, B.Sc.
WILLIAM HUGGINS, Esq., D.C.L., LL.D., Ph.D., F.R.S., F.R.A.S., Hon. F.R.S.E. CARDIFF, August 19, 1891.	The Right Hon. Lord Windsor, Lord-Lieutenant of Glamorganshire The Most Hon. the Marquess of Bute, K.T. The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S. The Right Hon. Lord Tredegar The Right Hon. Lord Aberdare, G.C.B., F.R.S., F.R.G.S. Sir J. T. D. Llewelyn, Bart., F.Z.S. Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., Pres.G.S. Sir Robert Ball, LL.D., F.R.S., F.R.A.S., Royal Astronomer of Ireland	R. W. Atkinson, Esq., B.Sc., F.C.S., F.I.C. Professor H. W. Lloyd Tanner, M.A., F.R.A.S.
SIR ARCHIBALD GEIKIE, LL.D., D.Sc., For. Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom EDINBURGH, August 3, 1892.	The Right Hon. the Lord Provost of Edinburgh The Most Hon. the Marquess of Lothian, K.T. The Right Hon. the Earl of Rosebery, LL.D., F.R.S., F.R.S.E. The Right Hon. J. H. A. Macdonald, C.B., LL.D., F.R.S., F.R.S.E. Principal Sir William Muir, K.C.S.I., D.C.L. Professor Sir Douglas Maclagan, M.D., Pres.R.S.E. Professor Sir William Turner, F.R.S., F.R.S.E. Professor P. G. Tait, M.A., F.R.S.E. Professor A. Crum Brown, M.D., F.R.S., F.R.S.E., Pres.C.S.	Professor G. F. Armstrong, M.A., M.Inst.C.E., F.R.S.E., F.G.S. F. Grant Ogilvie, Esq., M.A., B.Sc., F.R.S.E. John Harrison, Esq.
DR. J. S. BURDON SANDERSON, M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford NOTTINGHAM, September 13, 1893.	His Grace the Duke of St. Albans, Lord-Lieutenant of Nottinghamshire His Grace the Duke of Devonshire, K.G., Chancellor of the University of Cambridge His Grace the Duke of Portland His Grace the Duke of Newcastle The Right Hon. Lord Belper The Mayor of Nottingham The Right Hon. Sir W. R. Grove, F.R.S. Sir John Turney, J.P. Professor Michael Foster, M.A., Sec.R.S. W. H. Ransom, Esq., M.D., F.R.S.	Professor F. Clowes, D.Sc. Professor W. H. Heaton, M.A. Arthur Williams, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The MOST HON. THE MARQUIS OF SALISBURY, K.G., D.C.L., F.R.S., Chancellor of the University of Oxford. OXFORD, August 8, 1894.	The Right Hon. the Earl of Jersey, G.C.M.G., Lord-Lieutenant of the County of Oxford The Right Hon. Lord Wantage, K.C.B., V.C., Lord-Lieutenant of Berkshire The Right Hon. the Earl of Rosebery, K.G., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Oxford, D.D. The Right Hon. Lord Rothschild, Lord-Lieutenant of Buckinghamshire The Right Hon. Lord Kelvin, D.C.L., Pres.R.S. The Rev. the Vice-Chancellor of the University of Oxford The Mayor of Oxford Sir W. R. Anson, D.C.L., Warden of All Souls College Sir Bernhard Samuelson, Bart., M.P., F.R.S. Sir Henry Dyke Acland, Bart., M.D., F.R.S., Regius Professor of Medicine The Rev. B. Price, D.D., F.R.S., Sedleian Professor of Natural Philosophy Dr. J. J. Sylvester, F.R.S., Savilian Professor of Geometry	Gilbert C. Bourne, Esq., M.A. G. C. Druce, Esq., M.A. D. H. Nagel, Esq., M.A.
CAPTAIN SIR DOUGLAS GALTON, K.C.B., D.C.L., LL.D., F.R.S., F.R.G.S., F.G.S. IPSWICH, September 11, 1895.	The Most Hon. the Marquis of Bristol, M.A., Lord-Lieutenant of the County of Suffolk The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge The Right Hon. Lord Rayleigh, Sec.R.S., Lord-Lieutenant of Essex The Right Hon. Lord Gwydyr, M.A., High Steward of Ipswich The Right Hon. Lord Henniker, F.S.A. The Right Hon. Lord Rendlesham J. H. Bartlet, Esq., Mayor of Ipswich Sir G. G. Stokes, Bart., D.C.L., F.R.S. Dr. E. Frankland, D.C.L., F.R.S. Professor G. H. Darwin, M.A., F.R.S. Felix T. Cobbold, Esq., M.A.	G. H. Hewetson, Esq. S. A. Notcutt, Esq., B.A., LL.M. B.Sc. E. P. Ridley, Esq.
SIR JOSEPH LISTER, Bart., D.C.L., LL.D., President of the Royal Society. LIVERPOOL, September 16, 1896.	The Right Hon. the Earl of Derby, G.C.B., Lord Mayor of Liverpool. The Right Hon. the Earl of Sefton, K.G., Lord-Lieutenant of Lancashire Sir W. B. Forwood, J.P. Sir Henry E. Roscoe, D.C.L., F.R.S. The Principal of University College, Liverpool W. Rathbone, Esq., LL.D. W. Crookes, Esq., F.R.S., V.P.C.S. T. H. Ismay, Esq., J.P., D.L. Professor A. Liversidge, F.R.S.	Professor W. A. Herdman, F.R.S. Isaac C. Thompson, Esq., F.L.S. W. E. Willink, Esq.
SIR JOHN EVANS, K.C.B., D.C.L., LL.D., Sc.D., Treas.R.S., F.S.A., For. Sec. G. S. TORONTO, August 18, 1897.	His Excellency the Right Hon. the Earl of Aberdeen, G.C.M.G., Governor-General of the Dominion of Canada The Right Hon. Lord Rayleigh, M.A., D.C.L., F.R.S. The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S., F.R.S.E. The Hon. Sir Wilfrid Laurier, G.C.M.G., Prime Minister of the Dominion of Canada His Honour the Lieutenant-Governor of the Province of Ontario The Hon. the Premier of the Province of Ontario The Hon. the Minister of Education for the Province of Ontario The Hon. Sir Charles Tupper, Bart., G.C.M.G., C.B., LL.D. The Hon. Sir Donald A. Smith, G.C.M.G., LL.D., High Commissioner for Canada Sir William Dawson, C.M.G., F.R.S. The Mayor of Toronto Professor J. Loudon, M.A., LL.D., President of the University of Toronto	Professor A. B. Macallum, M.B., Ph.D. B. E. Walker, Esq., F.G.S. J. S. Willison, Esq.

SIR WILLIAM CROOKES, F.R.S., V.P.C.S. BRISTOL, September 7, 1898.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Rev. the Lord Bishop of Bristol, D.D. The Right Hon. Sir Edward Fry, D.C.L., F.R.S., F.S.A. Sir F. J. Bramwell, Bart., D.C.L., LL.D., F.R.S. The Right Worshipful the Mayor of Bristol The Principal of University College, Bristol The Master of the Society of Merchant Venturers of Bristol John Beddoe, Esq., M.D., LL.D., F.R.S. Professor T. G. Bonney, D.Sc., LL.D., F.R.S., F.S.A., F.G.S.	Arthur Lee, Esq., J.P. Bertram Rogers, Esq., M.D.
PROFESSOR SIR MICHAEL FOSTER, K.C.B., M.D., D.C.L., LL.D., Sec. R.S. DOVER, September 13, 1899.	His Grace the Lord Archbishop of Canterbury, D.D. The Most Hon. the Marquis of Salisbury, K.G., M.A., D.C.L., F.R.S. The Mayor of Dover The Major-General Commanding the South-Eastern District The Right Hon. A. Akers-Douglas, M.P. The Very Rev. F. W. Farrar, D.D., F.R.S., Dean of Canterbury Sir J. Norman Lockyer, K.C.B., F.R.S. Professor G. H. Darwin, M.A., LL.D., F.R.S., Pres. R.A.S.	E. Wollaston Knocker, Esq., C.B. W. H. Pendlebury, Esq., M.A.
PROFESSOR SIR WILLIAM TURNER, M.B., D.Sc., D.C.L., LL.D., F.R.S. BRADFORD, September 5, 1900.	The Right Hon. the Earl of Scarbrough, Lord-Lieutenant of the West Riding of Yorkshire His Grace the Duke of Devonshire, K.G., D.C.L., LL.D., F.R.S. The Most Hon. the Marquis of Ripon, K.G., G.C.S.I., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Lord Masham His Worship the Mayor of Bradford The Hon. H. E. Butler, Lord of the Manor, Bradford Sir Alexander Binnie, M.Inst.C.E., F.G.S. Professor A. W. Rücker, M.A., D.Sc., Sec.R.S. Dr. T. E. Thorpe, Sc.D., F.R.S., Pres.C.S. Principal N. Bodington, Litt.D., Vice-Chancellor of the Victoria University Professor L. C. Miall, F.R.S.	Ramsden Bacchus, Esq. J. E. Fawcett, Esq., J.P. Frederick Stevens, Esq.
PROFESSOR A. W. RÜCKER, M.A., LL.D., D.Sc., Sec.R.S. GLASGOW, September 11, 1901.	The Right Hon. the Earl of Glasgow, G.C.M.G. The Right Hon. the Lord Blythswood, LL.D., D.L. The Right Hon. the Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S. Samuel Chisholm, Esq., the Hon. the Lord Provost of Glasgow Very Rev. R. Herbert Story, D.D., LL.D., Principal of the University of Glasgow Sir John Maxwell Stirling-Maxwell, Bart., M.P., D.L. Sir Andrew Noble, K.C.B., D.C.L., F.R.S. Sir Archibald Geikie, D.C.L., LL.D., F.R.S. Sir W. T. Thiselton-Dyer, K.C.M.G., C.I.E., F.R.S. James Parker Smith, Esq., M.P., D.L. John Inglis, Esq., LL.D. Professor John Cleland, M.D., LL.D., D.Sc., F.R.S.	Sir J. D. Marwick, LL.D., D.L., F.R.S.E. Professor John Young, M.D. Professor Magnus Maclean, D.Sc., F.R.S.E.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR JAMES DEWAR, M.A., LL.D., D.Sc., F.R.S. BELFAST, September 10, 1902.	His Grace the Duke of Abercorn, K.G., H.M. Lieutenant of the County of Donegal The Marquis of Londonderry, K.G., H.M. Lieutenant of the City of Belfast Sir Francis Macnaghten, Bart., H.M. Lieutenant of the County of Antrim The Right Hon. the Earl of Shaftesbury, D.L. The Right Hon. the Earl of Rosse, K.P., D.C.L., LL.D., F.R.S. The Right Hon. Thomas Sinclair, D.Lit. Sir William Quartus Ewart, Bart., M.A. The Lord Mayor of Belfast The President of Queen's College, Belfast Professor E. Ray Lankester, M.A., F.R.S. Professor Peter Redfern, M.D.	John Brown, Esq., F.R.S. Godfrey W. Ferguson, Esq. Professor Maurice FitzGerald, B.A.
SIR NORMAN LOCKYER, K.C.B., LL.D., F.R.S., Correspondant de l'Institut de France SOUTHPORT, September 9, 1903.	The Right Hon. the Earl of Derby, K.G., G.C.B. The Right Hon. the Earl of Crawford and Balcarres, K.T., LL.D., F.R.S. The Right Hon. the Earl Spencer, K.G., LL.D., Chancellor of the Victoria University The Right Hon. the Earl of Sefton The Right Hon. the Earl of Lathom Sir Henry Roscoe, B.A., Ph.D., LL.D., D.C.L., F.R.S. Sir George A. Pilkington Alfred Hopkinson, Esq., LL.D., K.C., Vice-Chancellor of the Victoria University T. T. L. Scarisbrick, Esq., Mayor of Southport E. Marshall Hall, Esq., K.C., M.P. for Southport Charles H. B. Hesketh, Esq. Charles Scarisbrick, Esq., J.P. Charles Weld Blundell, Esq.	Harold Brodrick, Esq., M.A. J. Ernest Jarratt, Esq.
The RIGHT HON. A. J. BALFOUR, D.C.L., LL.D., M.P., F.R.S., Chancellor of the University of Edinburgh CAMBRIDGE, August 17, 1904.	His Grace the Duke of Devonshire, K.G., LL.D., F.R.S., Chancellor of the University of Cambridge Alexander Peckover, Esq., LL.D., Lord Lieutenant of Cambridgeshire Arthur Hall, Esq., M.A., D.L., High Sheriff of Cambridgeshire and Huntingdonshire The Right Rev. the Lord Bishop of Ely, D.D. The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge The Right Hon. Lord Rayleigh, D.C.L., LL.D., F.R.S. The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S. The Rev. F. H. Chase, D.D., Vice-Chancellor of the University and President of Queens' College, Cambridge The Very Rev. H. Montagu Butler, D.D., Master of Trinity Mrs. Sidgwick, Principal of Newnham College, Cambridge J. H. Chesshyre Dalton, Esq., M.D., Mayor of Cambridge Robert Stephenson, Esq., Chairman of the Cambridgeshire County Council Joseph Martin, Esq., Chairman of the Isle of Ely County Council P. H. Young, Esq., Deputy Mayor of Cambridge	S. R. Ginn, Esq., D.L. A. Hutchinson, Esq., M.A. A. C. Seward, Esq., M.A., F.R.S. S. Skinner, Esq., M.A. J. E. L. Whitehead, Esq., M.A.

Presidents	Vice-Presidents	Local Secretaries
PROFESSOR G. H. DARWIN, M.A., LL.D., Ph.D., F.R.S. SOUTH AFRICA, August 15, 1905.	His Excellency the Right Hon. the Earl of Selborne, G.C.M.G., High Commissioner for South Africa The Right Hon. Lord Milner, G.C.B., G.C.M.G., late High Commissioner for South Africa His Excellency the Hon. Sir Walter F. Hely-Hutchinson, G.C.M.G., Governor of Cape Colony His Excellency Colonel Sir Henry E. McCallum, K.C.M.G., R.E., Governor of Natal His Excellency Captain the Hon. Sir Arthur Lawley, K.C.M.G., Lieutenant-Governor, Transvaal His Excellency Major Sir H. J. Goold-Adams, K.C.M.G., Lieutenant-Governor, Orange River Colony His Honour Sir W. H. Milton, K.C.M.G., Administrator of Southern Rhodesia. Sir Charles H. T. Metcalfe, Bart., M.A. Sir David Gill, K.C.B., LL.D., F.R.S., H.M. Astronomer, Cape Colony ... Theodore Reunert, M.Inst.C.E. The Mayor of Cape Town The Mayor of Johannesburg The President of the Philosophical Society of South Africa The Mayor of Durban The Mayor of Pietermaritzburg The Mayor of Bloemfontein The Mayor of Pretoria The Mayor of Kimberley The Mayor of Bulawayo	*Cape Town:—* Professor J. C. Beattie, D.Sc., F.R.S.E. E. J. Cattell, J.P. J. R. Finch. Rev. Wm. Flint, D.D. E. Hope Jones. W. L. Sclater, M.A. *Johannesburg:—* W. E. Cursons F. Rowland. *Central Organising Committee for South Africa:—* *Chairman.*—Sir David Gill, K.C.B., F.R.S. *Hon. Secretaries.*—J. D. F. Gilchrist, M.A., Ph.D. (Cape Town); W. Cullen (Johannesburg).
PROFESSOR E. RAY LANKESTER, M.A., LL.D., D.Sc., F.R.S., F.L.S., Director of the Natural History Departments of the British Museum. YORK, August 1, 1906.	His Grace the Archbishop of York, D.D., D.C.L., M.A. The Right Hon. the Lord Mayor of York The High Sheriff of Yorkshire The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S. The Right Hon. the Earl of Feversham The Right Rev. the Lord Bishop of Ripon, D.D., D.C.L. The Right Hon. Lord Avebury, D.C.L., LL.D., F.R.S. The Right Hon. Lord Wenlock, G.C.S.I., G.C.I.E., K.C.B. Sir Hugh Bell, Bart. Sir George S. Gibb Tempest Anderson, M.D., D.Sc., President of the Yorkshire Philosophical Society. John Stephenson Rowntree	Henry Craven. C. E. Elmhirst.
SIR DAVID GILL, K.C.B., LL.D., F.R.S., Hon. F.R.S.E. LEICESTER, July 31, 1907.	His Grace the Duke of Rutland, Lord Lieutenant of Leicestershire Richard Dalgliesh, J.P., D.L., High Sheriff of Leicestershire Sir Edward Wood, J.P., Mayor of Leicester The Right Hon. the Earl of Dysart The Right Hon. the Earl Howe, G.C.V.O. The Right Rev. the Lord Bishop of Peterborough, D.D. The Right Rev. the Bishop of Leicester, D.D. Sir Oliver Lodge, D.Sc., LL.D., F.R.S., Principal of the University of Birmingham Herbert Ellis, President of the Leicester Literary and Philosophical Society	Alfred Colson, M.Inst.C.E. E. V. Hiley.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
FRANCIS DARWIN, M.A., M.B., LL.D., F.R.S. DUBLIN, September 2, 1908.	Right Hon. Alderman Gerald O'Reilly, Lord Mayor of Dublin Right Hon. Sir Samuel Walker, Bart., Lord Chancellor of Ireland Right Hon. Augustine Birrell, M.P., Chief Secretary to the Lord Lieutenant of Ireland Right Hon. the Earl of Meath, K.P., His Majesty's Lieutenant for the County of Dublin Right Hon. Lord Castletown of Upper Ossory, K.P., Chancellor of the Royal University of Ireland Anthony Traill, M.D., LL.D., Provost of Trinity College, Dublin Very Rev. William Delany, LL.D., President of University College, Dublin Right Hon. Viscount Iveagh, K.P., LL.D., F.R.S. Right Hon. Lord Ardilaun, D.L., LL.D., President of the Royal Dublin Society Francis A. Tarleton, LL.D., President of the Royal Irish Academy Right Hon. Mr. Justice Madden, M.A., LL.D., Vice-Chancellor of the University of Dublin Sir Christopher Nixon, Bart., M.D., LL.D., Vice-Chancellor of the Royal University of Ireland T. W. Russell, M.P., Vice-President of the Department of Agriculture and Technical Instruction in Ireland	Joseph McGrath, LL.D. John Mulligan, J. P. Professor W. H. Thompson, D.Sc., M.D. Professor W. E. Thrift, M.A.
PROFESSOR SIR J. J. THOMSON, M.A., Sc.D., D.Sc., F.R.S. WINNIPEG, August 25, 1909.	The Right Hon. Lord Strathcona and Mount Royal, G.C.M.G., G.C.V.O., LL.D., High Commissioner in London for the Dominion of Canada The Right Hon. Sir Wilfrid Laurier, G.C.M.G., P.C., D.L., Prime Minister and President of Privy Council The Hon. Sir Daniel Hunter McMillan, K.C.M.G., Lieutenant-Governor of Manitoba The Hon. Rodmond Palen Roblin, Premier of Manitoba The Hon. Amedee E. Forget, Lieutenant-Governor of Saskatchewan The Hon. Walter Scott, Premier of Saskatchewan The Hon. George H. V. Bulyea, Lieutenant-Governor of Alberta The Hon. Alex. C. Rutherford, B.A., LL.D., Premier of Alberta The Hon. James Dunsmuir, Lieutenant-Governor of British Columbia The Hon. Richard McBride, LL.B., K.C., Premier of British Columbia	C. N. Bell. W. Sanford Evans. Professor M. A. Parker, B.Sc., F.C.S. Professor Swale Vincent, M.D., D.Sc.

TRUSTEES AND GENERAL OFFICERS, 1831–1909.

TRUSTEES.

1832–70 (Sir) R. I. MURCHISON (Bart.), F.R.S.
1832–62 JOHN TAYLOR, Esq., F.R.S.
1832–39 C. BABBAGE, Esq., F.R.S.
1839–44 F. BAILY, Esq., F.R.S.
1844–58 Rev. G. PEACOCK, F.R.S.
1858–82 General E. SABINE, F.R.S.
1862–81 Sir P. EGERTON, Bart., F.R.S.
1872 Sir J. LUBBOCK, Bart. (now Lord AVEBURY), F.R.S.
1881–83 W. SPOTTISWOODE, Esq., Pres. R.S.
1883 Lord RAYLEIGH, F.R.S.
1883–98 Sir LYON (afterwards Lord) PLAYFAIR, F.R.S.
1898 Prof. (Sir) A. W. RÜCKER, F.R.S.

GENERAL TREASURERS.

1831 JONATHAN GRAY, Esq.
1832–62 JOHN TAYLOR, Esq., F.R.S.
1862–74 W. SPOTTISWOODE, Esq., F.R.S.
1874–91 Prof. A. W. WILLIAMSON, F.R.S.
1891–98 Prof. (Sir) A. W. RÜCKER, F.R.S.
1898–1904 Prof. G. C. FOSTER, F.R.S.
1904 Prof. JOHN PERRY, F.R.S.

GENERAL SECRETARIES.

1832–35 Rev. W. VERNON HARCOURT, F.R.S.
1835–36 Rev. W. VERNON HARCOURT, F.R.S., and F. BAILY, Esq., F.R.S.
1836–37 Rev. W. VERNON HARCOURT, F.R.S., and R. I. MURCHISON, Esq., F.R.S.
1837–39 R. I. MURCHISON, Esq., F.R.S., and Rev. G. PEACOCK, F.R.S.
1839–45 Sir R. I. MURCHISON, F.R.S., and Major E. SABINE, F.R.S.
1845–50 Lieut.-Colonel E. SABINE, F.R.S.
1850–52 General E. SABINE, F.R.S., and J. F. ROYLE, Esq., F.R.S.
1852–53 J. F. ROYLE, Esq., F.R.S.
1853–59 General E. SABINE, F.R.S.
1859–61 Prof. R. WALKER, F.R.S.
1861–62 W. HOPKINS, Esq., F.R.S.
1862–63 W. HOPKINS, Esq., F.R.S., and Prof. J. PHILLIPS, F.R.S.
1863–65 W. HOPKINS, Esq., F.R.S., and F. GALTON, Esq., F.R.S.
1865–66 F. GALTON, Esq., F.R.S.
1866–68 F. GALTON, Esq., F.R.S., and Dr. T. A. HIRST, F.R.S.
1868–71 Dr. T. A. HIRST, F.R.S., and Dr T. THOMSON, F.R.S.
1871–72 Dr. T. THOMSON, F.R.S., and Capt. DOUGLAS GALTON, F.R.S.
1872–76 Capt. D. GALTON, F.R.S., and Dr. MICHAEL FOSTER, F.R.S.
1876–81 Capt. D. GALTON, F.R.S., and Dr. P. L. SCLATER, F.R.S.
1881–82 Capt. D. GALTON, F.R.S., and Prof. F. M. BALFOUR, F.R.S.
1882–83 Capt. DOUGLAS GALTON, F.R.S.
1883–95 Sir DOUGLAS GALTON, F.R.S., and A. G. VERNON HARCOURT, Esq., F.R.S.
1895–97 A. G. VERNON HARCOURT, Esq., F.R.S., and Prof. E. A. SCHÄFER, F.R.S.
1897–1900 Prof. SCHÄFER, F.R.S., and Sir W. C. ROBERTS-AUSTEN, F.R.S.
1900–02 Sir W. C. ROBERTS-AUSTEN, F.R.S., and Dr. D. H. SCOTT, F.R.S.
1902–03 Dr. D. H. SCOTT, F.R.S., and Major P. A. MACMAHON, F.R.S.
1903 Major P. A. MACMAHON, F.R.S., and Prof. W. A. HERDMAN, F.R.S.

ASSISTANT GENERAL SECRETARIES, &c.: 1831–1904.

1831 JOHN PHILLIPS, Esq., *Secretary.*
1832 Prof. J. D. FORBES, *Acting Secretary.*
1832–62 Prof. JOHN PHILLIPS, F.R.S.
1862–78 G. GRIFFITH, Esq., M.A.
1878–80 J. E. H. GORDON, Esq., B.A., *Assistant Secretary.*
1881 G. GRIFFITH, Esq., M.A., *Acting Secretary.*
1881–85 Prof. T. G. BONNEY, F.R.S., *Secretary.*
1885–90 A. T. ATCHISON, Esq., M.A., *Secretary.*
1890 G. GRIFFITH, Esq., M.A., *Acting Secretary.*
1890–1902 G. GRIFFITH, Esq., M.A.
1902–04 J. G. GARSON, Esq., M.D.

ASSISTANT SECRETARIES.

1904–09 A. SILVA WHITE, Esq.
1909 O. J. R. HOWARTH, Esq., M.A.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries
MATHEMATICAL AND PHYSICAL SCIENCES.		
COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.		
1832. Oxford......	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.
SECTION A.—MATHEMATICS AND PHYSICS.		
1835. Dublin......	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol......	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool...	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S....	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S............	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.......	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork.........	Prof. M'Culloch, M.R.I.A. ...	J. Nott, Prof. Stevelly.
1844. York.........	The Earl of Rosse, F.R.S. ...	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford......	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.......	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast......	Prof. W. Thomson, M.A., F.R.S., F.R.S.E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull.........	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S., F.R.S.E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin......	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford......	Rev. B. Price, M.A., F.R.S....	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter......	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford...	Prof. H. J. S. Smith, F.R.S. .	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol......	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin......	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1881. York.........	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	Prof. W. E. Ayrton, Dr. O. J. Lodge, D. MacAlister, Rev. W. Routh.
1882. Southampton.	Rt. Hon. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Dr. O. J. Lodge, D. MacAlister, Rev. G. Richardson.
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Prof. R. C. Rowe.
1884. Montreal ...	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	C. Carpmael, W. M. Hicks, A. Johnson, O. J. Lodge, D. MacAlister.
1885. Aberdeen...	Prof. G. Chrystal, M.A., F.R.S.E.	R. E. Baynes, R. T. Glazebrook, Prof. W. M. Hicks, Prof. W. Ingram.

Date and Place	Presidents	Secretaries
1886. Birmingham	Prof. G. H. Darwin, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. J. H. Poynting, W. N. Shaw.
1887. Manchester	Prof. Sir R. S. Ball, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. H. Lamb, W. N. Shaw.
1888. Bath.........	Prof. G. F. Fitzgerald, M.A., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw.
1889. Newcastle-upon-Tyne	Capt. W. de W. Abney, C.B., R.E., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw, H. Stroud.
1890. Leeds	J. W. L. Glaisher, Sc.D., F.R.S., V.P.R.A.S.	R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. W. Stroud.
1891. Cardiff......	Prof. O. J. Lodge, D.Sc., LL.D., F.R.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Prof. A. L. Selby.
1892. Edinburgh	Prof. A. Schuster, Ph.D., F.R.S., F.R.A.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1893. Nottingham	R. T. Glazebrook, M.A., F.R.S.	W. T. A. Emtage, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1894. Oxford	Prof. A. W. Rücker, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, J. Walker.
1895. Ipswich ...	Prof. W. M. Hicks, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, G. T. Walker, W. Watson.
1896. Liverpool...	Prof. J. J. Thomson, M.A., D.Sc., F.R.S.	Prof. W. H. Heaton, J. L. Howard, Prof. A. Lodge, G. T. Walker, W. Watson.
1897. Toronto ...	Prof. A. R. Forsyth, M.A., F.R.S.	Prof. W. H. Heaton, J. C. Glashan, J. L. Howard, Prof. J. C. McLennan.
1898. Bristol	Prof. W. E. Ayrton, F.R.S. ...	A. P. Chattock, J. L. Howard, C. H. Lees, W. Watson, E. T. Whittaker.
1899. Dover	Prof. J. H. Poynting, F.R.S.	J. L. Howard, C. H. Lees, W. Watson, E. T. Whittaker.
1900. Bradford ...	Dr. J. Larmor, F.R.S.—*Dep. of Astronomy*, Dr. A. A. Common, F.R.S.	P. H. Cowell, A. Fowler, C. H. Lees, C. J. L. Wagstaffe, W. Watson, E. T. Whittaker.
1901. Glasgow ...	Major P. A. MacMahon, F.R.S. —*Dep. of Astronomy*, Prof. H. H. Turner, F.R.S.	H. S. Carslaw, C. H. Lees, W. Stewart, Prof. L. R. Wilberforce.
1902. Belfast......	Prof. J. Purser, LL.D., M.R.I.A. —*Dep. of Astronomy*, Prof. A. Schuster, F.R.S.	H. S. Carslaw, A. R. Hinks, A. Larmor, C. H. Lees, Prof. W. B. Morton, A. W. Porter.
1903. Southport	C. Vernon Boys, F.R.S.—*Dep. of Astronomy and Meteorology*, Dr. W. N. Shaw, F.R.S.	D. E. Benson, A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees, J. Loton, A. W. Porter.
1904. Cambridge	Prof. H. Lamb, F.R.S.—*Sub-Section of Astronomy and Cosmical Physics*, Sir J. Eliot, K.C.I.E., F.R.S.	A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees, Dr. W. J. S. Lockyer, A. W. Porter, W. C. D. Whetham.
1905. SouthAfrica	Prof. A. R. Forsyth, M.A., F.R.S.	A. R. Hinks, S. S. Hough, R. T. A. Innes, J. H. Jeans, Dr. C. H. Lees.
1906. York.........	Principal E. H. Griffiths, F.R.S.	Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter, H. Dennis Taylor.
1907. Leicester ...	Prof. A. E. H. Love, M.A., F.R.S.	E. E. Brooks, Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter.
1908. Dublin	Dr. W. N. Shaw, F.R.S.	Dr. W. G. Duffield, Dr. L. N. G. Filon, E. Gold, Prof. J. A. McClelland, Prof. A. W. Porter, Prof. E. T. Whittaker.
1909. Winnipeg	Prof. E. Rutherford, F.R.S.	Prof. F. Allen, Prof. J. C. Fields, E. Gold, F. Horton, Prof. A. W. Porter, Dr. A. A. Rambaut.

Date and Place	Presidents	Secretaries

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY, &c.

1832. Oxford......	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope...........................	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin......	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol......	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, R. Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E. ...	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull.........	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. H. Miller, M.A., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S.......	A. V. Harcourt, Prof. Liveing, R. Biggs.

Date and Place	Presidents	Secretaries
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. Y. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S................	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S. ...	H. S. Bell, W. Chandler Roberts, J. M. Thomson.
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. P. Bedson, H. B. Dixon, W. R. E. Hodgkinson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, F.R.S.	P. P. Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.
1884. Montreal ...	Prof. Sir H. E. Roscoe, Ph.D., LL.D., F.R.S.	Prof. P. Phillips Bedson, H. B. Dixon, T. McFarlane, Prof. W. H. Pike.
1885. Aberdeen...	Prof. H. E. Armstrong, Ph.D., F.R.S., Sec. C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, Dr. W. J. Simpson.
1886. Birmingham	W. Crookes, F.R.S., V.P.C.S.	P. P. Bedson, H. B. Dixon, H. F. Morley, W. W. J. Nicol, C. J. Woodward.
1887. Manchester	Dr. E. Schunck, F.R.S.	Prof. P. Phillips Bedson, H. Forster Morley, W. Thomson.
1888. Bath.........	Prof. W. A. Tilden, D.Sc., F.R.S., V.P.C.S.	Prof. H. B. Dixon, H. Forster Morley, R. E. Moyle, W. W. J. Nicol.
1889. Newcastle-upon-Tyne	Sir I. Lowthian Bell, Bart., D.C.L., F.R.S.	H. Forster Morley, D. H. Nagel, W. W. J. Nicol, H. L. Pattinson, jun.
1890. Leeds	Prof. T. E. Thorpe, B.Sc., Ph.D., F.R.S., Treas. C.S.	C. H. Bothamley, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1891. Cardiff	Prof. W. C. Roberts-Austen, C.B., F.R.S.	C. H. Bothamley, H. Forster Morley, W. W. J. Nicol, G. S. Turpin.
1892. Edinburgh	Prof. H. McLeod, F.R.S.......	J. Gibson, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1893. Nottingham	Prof. J. Emerson Reynolds, M.D., D.Sc., F.R.S.	J. B. Coleman, M. J. R. Dunstan, D. H. Nagel, W. W. J. Nicol.
1894. Oxford	Prof. H. B. Dixon, M.A., F.R.S.	A. Colefax, W. W. Fisher, Arthur Harden, H. Forster Morley.

Date and Place	Presidents	Secretaries

SECTION B (*continued*).—CHEMISTRY.

1895. Ipswich ...	Prof. R. Meldola, F.R.S.	E. H. Fison, Arthur Harden, C. A. Kohn, J. W. Rodger.
1896. Liverpool...	Dr. Ludwig Mond, F.R.S. ...	Arthur Harden, C. A. Kohn.
1897. Toronto ...	Prof. W. Ramsay, F.R.S.......	Prof. W. H. Ellis, A. Harden, C. A. Kohn, Prof. R. F. Ruttan.
1898. Bristol......	Prof. F. R. Japp, F.R.S.	C. A. Kohn, F. W. Stoddart, T. K. Rose.
1899. Dover	Horace T. Brown, F.R.S.......	A. D. Hall, C. A. Kohn, T. K. Rose, Prof. W. P. Wynne.
1900. Bradford ...	Prof. W. H. Perkin, F.R.S. ...	W. M. Gardner, F. S. Kipping, W. J. Pope, T. K. Rose.
1901. Glasgow ...	Prof. Percy F. Frankland, F.R.S.	W. C. Anderson, G. G. Henderson, W. J. Pope, T. K. Rose.
1902. Belfast......	Prof. E. Divers, F.R.S.........	R. F. Blake, M. O. Forster, Prof. G. G. Henderson, Prof. W. J. Pope.
1903. Southport	Prof. W. N. Hartley, D.Sc., F.R.S.	Dr. M. O. Forster, Prof. G. G. Henderson, J. Ohm, Prof. W. J. Pope.
1904. Cambridge	Prof. Sydney Young, F.R.S....	Dr. M. O. Forster, Prof. G. G. Henderson, Dr. H. O. Jones, Prof. W. J. Pope.
1905. SouthAfrica	George T. Beilby	W. A. Caldecott, Dr. M. O. Forster, Prof. G. G. Henderson, C. F. Juritz.
1906. York.........	Prof. Wyndham R. Dunstan, F.R.S.	Dr. E. F. Armstrong, Prof. A. W. Crossley, S. H. Davies, Prof. W. J. Pope.
1907. Leicester...	Prof. A. Smithells, F.R.S. ...	Dr. E. F. Armstrong, Prof. A. W. Crossley, J. H. Hawthorn, Dr. F. M. Perkin.
1908. Dublin	Prof. F. S. Kipping, F.R.S. ...	Dr. E. F. Armstrong, Dr. A. McKenzie, Dr. F. M. Perkin, Dr. J. H. Pollock.
1909. Winnipeg...	Prof. H. E. Armstrong, F.R.S.	Dr. E. F. Armstrong, Dr. T. M. Lowry, Dr. F. M. Perkin, J. W. Shipley.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford......	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh	Prof. Jameson	J. Phillips, T. J. Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin......	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol......	Rev. Dr. Buckland, F.R.S.—*Geog.*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Capt. H. M. Denham, R.N.
1838. Newcastle..	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhoe.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, H. Murray, H. E. Strickland, J. Scoular.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S. ...	F. M. Jennings, H. E. Strickland.

Date and Place	Presidents	Secretaries
1844. York.........	Henry Warburton, Pres. G. S.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge	Rev. Prof. Sedgwick, M.A. F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham, Dr. C. T. Beke.
1847. Oxford......	Very Rev.Dr.Buckland,F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, F.R.S.	S.Benson,Prof.Oldham,Prof.Ramsay
1849. Birmingham	Sir Charles Lyell, F.R.S.......	J. B. Jukes, Prof. Oldham, A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	William Hopkins,M.A.,F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool...	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	J. Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, G. Sanders, R. H. Scott.
1858. Leeds	William Hopkins,M.A.,F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, F.R.S...	Prof. Harkness, E. Hull, J. W. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B., F.R.S.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S.......	E. Hull, W. Pengelly, H. Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M.Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, F.R.S.	L.C.Miall,R.H.Tiddeman,W.Topley.

[1] Geography was constituted a separate Section, see page lxxix.

Date and Place	Presidents	Secretaries
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol......	Dr. T. Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth...	W. Pengelly, F.R.S., F.G.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S. F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. M. Duncan, F.R.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, F.R.S., F.G.S....	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal ...	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.
1885. Aberdeen ...	Prof. J. W. Judd, F.R.S., Sec. G.S.	C. E. De Rance, J. Horne, J. J. H. Teall, W. Topley.
1886. Birmingham	Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.	W. J. Harrison, J. J. H. Teall, W. Topley, W. W. Watts.
1887. Manchester	Henry Woodward, LL.D., F.R.S., F.G.S.	J. E. Marr, J. J. H. Teall, W. Topley, W. W. Watts.
1888. Bath.........	Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S.	Prof G. A. Lebour, W. Topley, W. W. Watts, H. B. Woodward.
1889. Newcastle-upon-Tyne	Prof. J. Geikie, LL.D., D.C.L., F.R.S., F.G.S.	Prof. G. A. Lebour, J. E. Marr, W. W. Watts, H. B. Woodward.
1890. Leeds	Prof. A. H. Green, M.A., F.R.S., F.G.S.	J. E. Bedford, Dr. F. H. Hatch, J. E. Marr, W. W. Watts.
1891. Cardiff......	Prof. T. Rupert Jones, F.R.S., F.G.S.	W. Galloway, J. E. Marr, Clement Reid, W. W. Watts.
1892. Edinburgh	Prof. C. Lapworth, LL.D., F.R.S., F.G.S.	H. M. Cadell, J. E. Marr, Clement Reid, W. W. Watts.
1893. Nottingham	J. J. H. Teall, M.A., F.R.S., F.G.S.	J. W. Carr, J. E. Marr, Clement Reid, W. W. Watts.
1894. Oxford......	L. Fletcher, M.A., F.R.S. ...	F. A. Bather, A. Harker, Clement Reid, W. W. Watts.
1895. Ipswich ...	W. Whitaker, B.A., F.R.S. ...	F. A. Bather, G. W. Lamplugh, H. A. Miers, Clement Reid.
1896. Liverpool...	J. E. Marr, M.A., F.R.S.......	J. Lomas, Prof. H. A. Miers, C. Reid.
1897. Toronto ...	Dr. G. M. Dawson, C.M.G., F.R.S.	Prof. A. P. Coleman, G. W. Lamplugh, Prof. H. A. Miers.
1898. Bristol......	W. H. Hudleston, F.R S.......	G. W. Lamplugh, Prof. H. A. Miers, H. Pentecost.
1899. Dover	Sir Archibald Geikie, F.R.S.	J. W. Gregory, G. W. Lamplugh, Capt. McDakin, Prof. H. A. Miers.
1900. Bradford ...	Prof. W. J. Sollas, F.R.S. ...	H. L. Bowman, Rev. W. L. Carter, G. W. Lamplugh, H. W. Monckton.
1901. Glasgow ...	John Horne, F.R.S.	H. L. Bowman, H. W. Monckton.
1902. Belfast......	Lieut.-Gen. C. A. McMahon, F.R.S.	H. L. Bowman, H. W. Monckton, J. St. J. Phillips, H. J. Seymour.
1903. Southport	Prof. W. W. Watts, M.A., M.Sc.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. W. Monckton.
1904. Cambridge	Aubrey Strahan, F.R.S.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. Woods.
1905. SouthAfrica	Prof. H. A. Miers, M.A., D.Sc., F.R.S.	H. L. Bowman, J. Lomas, Dr. Molengraaff, Prof. A. Young, Prof. R. B. Young.

Date and Place	Presidents	Secretaries
1906. York.........	G. W. Lamplugh, F.R.S.	H. L. Bowman, Rev. W. L. Carter, Rev. W. Johnson, J. Lomas.
1907. Leicester ...	Prof. J. W. Gregory, F.R.S....	Dr. F. W. Bennett, Rev. W. L. Carter, Prof. T. Groom, J. Lomas.
1908. Dublin......	Prof. John Joly, F.R.S.	Rev. W. L. Carter, J. Lomas, Prof. S. H. Reynolds, H. J. Seymour.
1909. Winnipeg...	Dr. A. Smith Woodward, F.R.S.	W. L. Carter, Dr. A. R. Dwerryhouse, R. T. Hodgson, Prof. S. H. Reynolds.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh	Prof. Graham.....................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin......	Dr. Allman........................	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay..................	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D.......	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork.........	William Thompson, F.L.S....	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. lxxviii.]

1848. Swansea ...	L. W. Dillwyn, F.R.S..........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S., F.R.S.E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull.........	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.

[1] At this Meeting Physiology and Anatomy were made a separate Committee for Presidents and Secretaries of which see p. lxxviii.

Date and Place	Presidents	Secretaries
1854. Liverpool...	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. E. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. E. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham.[1]	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.

1866. Nottingham	Prof. Huxley, F.R.S.—*Dep. of Physiol.*, Prof. Humphry, F.R.S.—*Dep. of Anthropol.*, A. R. Wallace.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh .	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.

[1] The title of Section D was changed to Biology.

Date and Place	Presidents	Secretaries
1874. Belfast......	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres.R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, F.R.S.—*Dep. of Anth.*, Prof. Rolleston, F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister.—*Dep. of Anthropol.*, F. Galton, F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S. —*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, F.R.S.—*Dep. of Anat. & Physiol.*, F. M. Balfour, F.R.S.—*Dep. of Anthropol.*, F. W. Rudler.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	R. Owen, F.R.S.—*Dep. of Anthropol.*, Prof. W.H. Flower, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.	Prof. A. Gamgee, M.D., F.R.S. —*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, F.L.S. —*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal[1]...	Prof. H. N. Moseley, M.A., F.R.S.	Prof. W. Osler, Howard Saunders, A. Sedgwick, Prof. R. R. Wright.
1885. Aberdeen ...	Prof. W. C. M'Intosh, M.D., LL.D., F.R.S., F.R.S.E.	W. Heape, J. McGregor-Robertson, J. Duncan Matthews, Howard Saunders, H. Marshall Ward.
1886. Birmingham	W. Carruthers, Pres. L.S., F.R.S., F.G.S.	Prof. T. W. Bridge, W. Heape, Prof. W. Hillhouse, W. L. Sclater, Prof. H. Marshall Ward.
1887. Manchester	Prof. A. Newton, M.A., F.R.S., F.L.S., V.P.Z.S.	C. Bailey, F. E. Beddard, S. F. Harmer, W. Heape, W. L. Sclater, Prof. H. Marshall Ward.

[1] Anthropology was made a separate Section, see p. lxxxv.

Date and Place	Presidents	Secretaries
1888. Bath	W. T. Thiselton-Dyer, C.M.G., F.R.S., F.L.S.	F. E. Beddard, S. F. Harmer, Prof. H. Marshall Ward, W. Gardiner, Prof. W. D. Halliburton.
1889. Newcastle-upon-Tyne	Prof. J. S. Burdon Sanderson, M.A., M.D., F.R.S.	C. Bailey, F. E. Beddard, S. F. Harmer, Prof. T. Oliver, Prof. H. Marshall Ward.
1890. Leeds	Prof. A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S.	S. F. Harmer, Prof. W. A. Herdman, S. J. Hickson, F. W. Oliver H. Wager, H. Marshall Ward.
1891. Cardiff	Francis Darwin, M.A., M.B., F.R.S., F.L.S.	F. E. Beddard, Prof. W. A. Herdman, Dr. S. J. Hickson, G. Murray, Prof. W. N. Parker, H. Wager.
1892. Edinburgh	Prof. W. Rutherford, M.D., F.R.S., F.R.S.E.	G. Brook, Prof. W. A. Herdman, G. Murray, W. Stirling, H. Wager.
1893. Nottingham[1]	Rev. Canon H. B. Tristram, M.A., LL.D., F.R.S.	G. C. Bourne, J. B. Farmer, Prof. W. A. Herdman, S. J. Hickson, W. B. Ransom, W. L. Sclater.
1894. Oxford[2] ...	Prof. I. Bayley Balfour, M.A., F.R.S.	W. W. Benham, Prof. J. B. Farmer, Prof. W. A. Herdman, Prof. S. J. Hickson, G. Murray, W. L. Sclater.

SECTION D (*continued*).—ZOOLOGY.

1895. Ipswich ...	Prof. W. A. Herdman, F.R.S.	G. C. Bourne, H. Brown, W. E. Hoyle, W. L. Sclater.
1896. Liverpool...	Prof. E. B. Poulton, F.R.S. ...	H. O. Forbes, W. Garstang, W. E. Hoyle.
1897. Toronto ...	Prof. L. C. Miall, F.R.S.	W. Garstang, W. E. Hoyle, Prof. E. E. Prince.
1898. Bristol	Prof. W. F. R. Weldon, F.R.S.	Prof. R. Boyce, W. Garstang, Dr. A. J. Harrison, W. E. Hoyle.
1899. Dover	Adam Sedgwick, F.R.S.	W. Garstang, J. Graham Kerr.
1900. Bradford ...	Dr. R. H. Traquair, F.R.S. ...	W. Garstang, J. G. Kerr, T. H. Taylor, Swale Vincent.
1901. Glasgow ...	Prof. J. Cossar Ewart, F.R.S.	J. G. Kerr, J. Rankin, J. Y. Simpson.
1902. Belfast......	Prof. G. B. Howes, F.R.S. ...	Prof. J. G. Kerr, R. Patterson, J. Y. Simpson.
1903. Southport	Prof. S. J. Hickson, F.R.S. ...	Dr. J. H. Ashworth, J. Barcroft, A. Quayle, Dr. J. Y. Simpson, Dr. H. W. M. Tims.
1904. Cambridge	William Bateson, F.R.S.	Dr. J. H. Ashworth, L. Doncaster, Prof. J. Y. Simpson, Dr. H. W. M. Tims.
1905. South Africa	G. A. Boulenger, F.R.S.	Dr. Pakes, Dr. Purcell, Dr. H. W. M. Tims, Prof. J. Y. Simpson.
1906. York.........	J. J. Lister, F.R.S.	Dr. J. H. Ashworth, L. Doncaster, Oxley Grabham, Dr. H. W. M. Tims.
1907. Leicester ...	Dr. W. E. Hoyle, M.A..........	Dr. J. H. Ashworth, L. Doncaster, E. E. Lowe, Dr. H. W. M. Tims.
1908. Dublin......	Dr. S. F. Harmer, F.R.S.......	Dr. J. H. Ashworth, L. Doncaster, Prof. A. Fraser, Dr. H. W. M. Tims
1909. Winnipeg...	Dr. A. E. Shipley, F.R.S. ...	C. A. Baragar, C. L. Boulenger, Dr. J. Pearson, Dr. H. W. M. Tims.

[1] Physiology was made a separate Section, see p. lxxxvi.

[2] The title of Section D was changed to Zoology.

Date and Place	Presidents	Secretaries

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. J. Haviland..................	Dr. H. J. H. Bond, Mr. G. E. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. J. C. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. P. M. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr.J.Brown, Prof. Couper, Prof. Reid.

SECTION E.—PHYSIOLOGY.

1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1] ...	Prof. Ogle, M.D., F.R.S.	T. K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin......	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir B. Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford......	Prof.G.Rolleston,M.D.,F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	G. E. Paget, M.D................	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath.........	Dr. Edward Smith, F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham.[2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. lxxi.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. J. C. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A. ...	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

[1] Sections D and E were incorporated under the title of 'Section D—Zoology and Botany, including Physiology' (see p. lxxiv). Section E, being then vacant, was assigned in 1851 to Geography.

[2] *Vide* note on page lxxiv.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, E. MacAdam, Dr. Norton Shaw.
1853. Hull.........	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres.R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, F. Galton, P. O'Callaghan, Dr. Norton Shaw, T. Wright.
1859. Aberdeen...	Rear-Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S..........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S..........	J.W.Clarke, Rev. J. Glover, Dr. Hunt Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham.	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

Date and Place	Presidents	Secretaries
1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H.W.Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	A. Buchan, A. Keith Johnston, Clements R. Markham, J. H. Thomas.
1872. Brighton ...	Francis Galton, F.R.S..........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol......	Lieut.-General Strachey, R.E., C.S.I., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. O. Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B.	H. W. Bates, F. E. Fox, E. C. Rye.

Date and Place	Presidents	Secretaries
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S., F.R.S.E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport...	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.
1885. Aberdeen...	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S. Keltie, J. S. O'Halloran, E. G. Ravenstein, Rev. G. A. Smith.
1886. Birmingham.	Maj.-Gen. Sir. F. J. Goldsmid, K.C.S.I., C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie, E. G. Ravenstein.
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1888. Bath.........	Col. Sir C. W. Wilson, R.E., K.C.B., F.R.S., F.R.G.S.	J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1889. Newcastle-upon-Tyne	Col. Sir F. de Winton, K.C.M.G., C.B., F.R.G.S.	J. S. Keltie, H. J. Mackinder, R. Sulivan, A. Silva White.
1890. Leeds	Lieut.-Col. Sir R. Lambert Playfair, K.C.M.G., F.R.G.S.	A. Barker, John Coles, J. S. Keltie, A. Silva White.
1891. Cardiff......	E. G. Ravenstein, F.R.G.S., F.S.S.	John Coles, J. S. Keltie, H. J. Mackinder, A. Silva White, Dr. Yeats.
1892. Edinburgh	Prof. J. Geikie, D.C.L., F.R.S., V.P.R.Scot.G.S.	J. G. Bartholomew, John Coles, J. S. Keltie, A. Silva White.
1893. Nottingham	H. Seebohm, Sec. R.S., F.L.S., F.Z.S.	Col. F. Bailey, John Coles, H. O. Forbes, Dr. H. R. Mill.
1894. Oxford......	Capt. W. J. L. Wharton, R.N., F.R.S.	John Coles, W. S. Dalgleish, H. N. Dickson, Dr. H. R. Mill.
1895. Ipswich ...	H. J. Mackinder, M.A., F.R.G.S.	John Coles, H. N. Dickson, Dr. H. R. Mill, W. A. Taylor.
1896. Liverpool...	Major L. Darwin, Sec. R.G.S.	Col. F. Bailey, H. N. Dickson, Dr. H. R. Mill, E. C. DuB. Phillips.
1897. Toronto ...	J. Scott Keltie, LL.D.	Col. F. Bailey, Capt. Deville, Dr. H. R. Mill, J. B. Tyrrell.
1898. Bristol......	Col. G. Earl Church, F.R.G.S.	H. N. Dickson, Dr. H. R. Mill, H. C. Trapnell.
1899. Dover	Sir John Murray, F.R.S.	H. N. Dickson, Dr. H. O. Forbes, Dr. H. R. Mill.
1900. Bradford ...	Sir George S. Robertson, K.C.S.I.	H. N. Dickson, E. Heawood, E. R. Wethey.
1901. Glasgow ...	Dr. H. R. Mill, F.R.G.S.	H. N. Dickson, E. Heawood, G. Sandeman, A. C. Turner.
1902. Belfast......	Sir T. H. Holdich, K.C.B. ...	G. G. Chisholm, E. Heawood, Dr. A. J. Herbertson, Dr. J. A. Lindsay.
1903. Southport...	Capt. E. W. Creak, R.N., C.B., F.R.S.	E. Heawood, Dr. A. J. Herbertson, E. A. Reeves, Capt. J. C. Underwood.
1904. Cambridge	Douglas W. Freshfield.........	E. Heawood, Dr. A. J. Herbertson, H. Y. Oldham, E. A. Reeves.
1905. SouthAfrica	Adm. Sir W. J. L. Wharton, R.N., K.C.B., F.R.S.	A. H. Cornish-Bowden, F. Flowers, Dr. A. J. Herbertson, H. Y. Oldham.
1906. York.........	Rt. Hon. Sir George Goldie, K.C.M.G., F.R.S.	E. Heawood, Dr. A. J. Herbertson, E. A. Reeves, G. Yeld.

Date and Place	Presidents	Secretaries
1907. Leicester...	George G. Chisholm, M.A. ...	E. Heawood, O. J. R. Howarth, E. A. Reeves, T. Walker.
1908. Dublin......	Major E. H. Hills, C.M.G., R.E.	W. F. Bailey, W. J. Barton, O. J. R. Howarth, E. A. Reeves.
1909. Winnipeg...	Col. Sir D. Johnston, K.C.M.G., C.B., R.E.	G. G. Chisholm, J. McFarlane, A. McIntyre.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.......	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin......	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol......	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham.	Henry Hallam, F.R.S..........	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.......	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. Cooke Tayler.
1843. Cork.........	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford......	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S. ...	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham.	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. P. G. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull.........	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin......	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines..................	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath	W. Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham.	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers............	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant-Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt.Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	E. Macrory, F. Purdy, C. T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872 Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, F. P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres. S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D. ...	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.
1881. York.........	Rt. Hon. M. E. Grant-Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.
1882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden-Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.
1884. Montreal ...	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.
1885. Aberdeen...	Prof. H. Sidgwick, LL.D., Litt.D.	Rev. W. Cunningham, Prof. H. S. Foxwell, C. McCombie, J. F. Moss.
1886. Birmingham.	J. B. Martin, M.A., F.S.S. ...	F. F. Barham, Rev. W. Cunningham, Prof. H. S. Foxwell, J. F. Moss.
1887. Manchester	Robert Giffen, LL.D., V.P.S.S.	Rev. W. Cunningham, F. Y. Edgeworth, T. H. Elliott, C. Hughes, J. E. C. Munro, G. H. Sargant.
1888. Bath.........	Rt. Hon. Lord Bramwell, LL.D., F.R.S.	Prof. F. Y. Edgeworth, T. H. Elliott, H. S. Foxwell, L. L. F. R. Price.
1889. Newcastle-upon-Tyne	Prof. F. Y. Edgeworth, M.A., F.S.S.	Rev. Dr. Cunningham, T. H. Elliott, F. B. Jevons, L. L. F. R. Price.
1890. Leeds	Prof. A. Marshall, M.A., F.S.S.	W. A. Brigg, Rev. Dr. Cunningham, T. H. Elliott, Prof. J. E. C. Munro, L. L. F. R. Price.
1891. Cardiff. ...	Prof. W. Cunningham, D.D., D.Sc., F.S.S.	Prof. J. Brough, E. Cannan, Prof. E. C. K. Gonner, H. Ll. Smith, Prof. W. R. Sorley.

Date and Place	Presidents	Secretaries
1892. Edinburgh	Hon. Sir C. W. Fremantle, K.C.B.	Prof. J. Brough, J. R. Findlay, Prof. E. C. K. Gonner, H. Higgs, L. L. F. R. Price.
1893. Nottingham	Prof. J. S. Nicholson, D.Sc., F.S.S.	Prof. E. C. K. Gonner, H. de B. Gibbins, J. A. H. Green, H. Higgs, L. L. F. R. Price.
1894. Oxford......	Prof. C. F. Bastable, M.A., F.S.S.	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1895. Ipswich ...	L. L. Price, M.A.	E. Cannan, Prof. E. C. K. Gonner, H. Higgs.
1896. Liverpool...	Rt. Hon. L. Courtney, M.P....	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1897. Toronto ...	Prof. E. C. K. Gonner, M.A.	E. Cannan, H. Higgs, Prof. A. Shortt.
1898. Bristol	J. Bonar, M.A., LL.D..........	E. Cannan, Prof. A. W. Flux, H. Higgs, W. E. Tanner.
1899. Dover	H. Higgs, LL.B.	A. L. Bowley, E. Cannan, Prof. A. W. Flux, Rev. G. Sarson.
1900. Bradford ...	Major P. G. Craigie, V.P.S.S.	A. L. Bowley, E. Cannan, S. J. Chapman, F. Hooper.
1901. Glasgow ...	Sir R. Giffen, K.C.B., F.R.S.	W. W. Blackie, A. L. Bowley, E. Cannan, S. J. Chapman.
1902. Belfast ...	E. Cannan, M.A., LL.D.	A. L. Bowley, Prof. S. J. Chapman, Dr. A. Duffin
1903. Southport	E. W. Brabrook, C.B.	A. L. Bowley, Prof. S. J. Chapman, Dr. B. W. Ginsburg, G. Lloyd.
1904. Cambridge	Prof. Wm. Smart, LL.D.	J. E. Bidwell, A. L. Bowley, Prof. S. J. Chapman, Dr. B. W. Ginsburg.
1905. SouthAfrica	Rev. W. Cunningham, D.D., D.Sc.	R. à Ababrelton, A. L. Bowley, Prof. H. E. S. Fremantle, H. O. Meredith.
1906. York.........	A. L. Bowley, M.A.	Prof. S. J. Chapman, D. H. Macgregor, H. O. Meredith, B. S. Rowntree.
1907. Leicester...	Prof. W. J. Ashley, M.A.......	Prof. S. J. Chapman, D. H. Macgregor, H. O. Meredith, T. S. Taylor.
1908. Dublin......	W. M. Acworth, M.A.	W. G. S. Adams, Prof. S. J. Chapman, Prof. D. H. Macgregor, H. O. Meredith.
	Sub-section of Agriculture—Rt. Hon. Sir H. Plunkett.	A. D. Hall, Prof. J. Percival, J. H. Priestley, Prof. J. Wilson.
1909. Winnipeg...	Prof. S. J. Chapman, M.A. ...	Prof. A. B. Clark, Dr. W. A. Manahan, Dr. W. R. Scott.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol......	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.......	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham.	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth...	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A....	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S..........	Rev. W. T. Kingsley.
1846. Southampton.	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford......	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.

Date and Place	Presidents	Secretaries
1848. Swansea ...	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robt. Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich ...	William Cubitt, F.R.S..........	John Head, Charles Manby.
1852. Belfast......	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull.........	William Fairbairn, F.R.S. ...	J. Oldham, J. Thomson, W. S. Ward.
1854. Liverpool...	John Scott Russell, F.R.S. ...	J. Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. M. Rankine, F.R.S. ...	L. Hill, W. Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, H. M. Jeffery.
1857. Dublin......	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge	William Fairbairn, F.R.S. ...	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer
1864. Bath.........	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham.	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P. Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S..........	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, A. Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	C. Barlow, H. Bauerman. E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast......	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	J. Abernethy, F.R.S.E..........	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton.	John Fowler, C.E., F.G.S. ...	A. T. Atchison, F. Churton, H. T. Wood.
1883. Southport...	J. Brunlees, Pres. Inst. C.E. ...	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal ...	Sir F. J. Bramwell, F.R.S., V.P. Inst. C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.

Date and Place	Presidents	Secretaries
1885. Aberdeen...	B. Baker, M.Inst.C.E.	A. T. Atchison, F. G. Ogilvie, E. Rigg, J. N. Shoolbred.
1886. Birmingham.	Sir J. N. Douglass, M.Inst. C.E.	C. W. Cooke, J. Kenward, W. B. Marshall, E. Rigg.
1887. Manchester	Prof. Osborne Reynolds, M.A., LL.D., F.R.S.	C. F. Budenberg, W. B. Marshall, E. Rigg.
1888. Bath.........	W. H. Preece, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, E. Rigg, P. K. Stothert.
1889. Newcastle-upon-Tyne.	W. Anderson, M.Inst.C.E. ...	C. W. Cooke, W. B. Marshall, Hon. C. A. Parsons, E. Rigg.
1890. Leeds	Capt. A. Noble, C.B., F.R.S., F.R.A.S.	E. K. Clark, C. W. Cooke, W. B. Marshall, E. Rigg.
1891. Cardiff......	T. Forster Brown, M.Inst.C.E.	C. W. Cooke, Prof. A. C. Elliott, W. B. Marshall, E. Rigg.
1892. Edinburgh	Prof. W. C. Unwin, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, W. C. Popplewell, E. Rigg.
1893. Nottingham	Jeremiah Head, M.Inst.C.E., F.C.S.	C. W. Cooke, W. B. Marshall, E. Rigg, H. Talbot.
1894. Oxford......	Prof. A. B. W. Kennedy, F.R.S., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, Rev. F. J. Smith.
1895. Ipswich ...	Prof. L. F. Vernon-Harcourt, M.A., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke. W. B. Marshall, P. G. M. Stoney.
1896. Liverpool...	Sir Douglas Fox, V.P.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, S. Dunkerley, W. B. Marshall.
1897. Toronto ...	G. F. Deacon, M.Inst.C.E. ...	Prof. T. Hudson Beare, Prof. Callendar, W. A. Price.
1898. Bristol......	Sir J. Wolfe-Barry, K.C.B., F.R.S.	Prof. T. H. Beare, Prof. J. Munro, H. W. Pearson, W. A. Price.
1899. Dover	Sir W. White, K.C.B., F.R.S.	Prof. T. H. Beare, W. A. Price, H. E. Stilgoe.
1900. Bradford [1]	Sir Alex. R. Binnie, M.Inst. C.E.	Prof. T. H. Beare, C. F. Charnock, Prof. S. Dunkerley, W. A. Price.

SECTION G.—ENGINEERING.

1901. Glasgow ...	R. E. Crompton, M.Inst.C.E.	H. Bamford, W. E. Dalby, W. A. Price.
1902. Belfast ...	Prof. J. Perry, F.R.S.	M. Barr, W. A. Price, J. Wylie.
1903. Southport	C. Hawksley, M.Inst.C.E. ...	Prof. W. E. Dalby, W. T. Maccall, W. A. Price.
1904. Cambridge	Hon. C. A. Parsons, F.R.S. ...	J. B. Peace, W. T. Maccall, W. A Price.
1905. SouthAfrica	Col. Sir C. Scott-Moncrieff, G.C.S.I., K.C.M.G., R.E.	W. T. Maccall, W. B. Marshall, Prof. H. Payne, E. Williams.
1906. York.........	J. A. Ewing, F.R.S.	W. T. Maccall, W. A. Price, J. Triffit.
1907. Leicester...	Prof. Silvanus P. Thompson, F.R.S.	Prof. E. G. Coker, A. C. Harris, W. A. Price, H. E. Wimperis.
1908. Dublin	Dugald Clerk, F.R.S.	Prof. E. G. Coker, Dr. W. E. Lilly, W. A. Price, H. E. Wimperis.
1909. Winnipeg...	Sir W. H. White, K.C.B., F.R.S.	E. E. Brydone-Jack, Prof. E. G. Coker, Prof. E. W. Marchant, W. A. Price.

SECTION H.—ANTHROPOLOGY.

1884. Montreal...	E. B. Tylor, D.C.L., F.R.S. ...	G. W. Bloxam, W. Hurst.
1885. Aberdeen...	Francis Galton, M.A., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. A. Macgregor.
1886. Birmingham.	Sir G. Campbell, K.C.S.I., M.P., D.C.L., F.R.G.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. R. Saundby.
1887. Manchester	Prof. A. H. Sayce, M.A.	G. W. Bloxam, Dr. J. G. Garson, Dr A. M. Paterson.

[1] The title of Section G was changed to Engineering.

Date and Place	Presidents	Secretaries
1888. Bath.........	Lieut.-General Pitt-Rivers, D.C.L., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, J. Harris Stone.
1889. Newcastle-upon-Tyne	Prof. Sir W. Turner, M.B., LL.D., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, Dr. R. Morison, Dr. R. Howden.
1890. Leeds	Dr. J. Evans, Treas. R.S., F.S.A., F.L.S., F.G.S.	G. W. Bloxam, Dr. C. M. Chadwick, Dr. J. G. Garson.
1891. Cardiff......	Prof. F. Max Müller, M.A. ...	G. W. Bloxam, Prof. R. Howden, H. Ling Roth, E. Seward.
1892. Edinburgh	Prof. A. Macalister, M.A., M.D., F.R.S.	G. W. Bloxam, Dr. D. Hepburn, Prof. R. Howden, H. Ling Roth.
1893. Nottingham	Dr. R. Munro, M.A. F.R.S.E.	G. W. Bloxam, Rev. T. W. Davies, Prof. R. Howden, F. B. Jevons, J. L. Myres.
1894. Oxford......	Sir W. H. Flower, K.C.B., F.R.S.	H. Balfour, Dr. J. G. Garson, H. Ling Roth.
1895. Ipswich ...	Prof. W. M. Flinders Petrie, D.C.L.	J. L. Myres, Rev. J. J. Raven, H. Ling Roth.
1896. Liverpool...	Arthur J. Evans, F.S.A.	Prof. A. C. Haddon, J. L. Myres, Prof. A. M. Paterson.
1897. Toronto ...	Sir W. Turner, F.R.S.	A. F. Chamberlain, H. O. Forbes, Prof. A. C. Haddon, J. L. Myres.
1898. Bristol......	E. W. Brabrook, C.B.	H. Balfour, J. L. Myres, G. Parker.
1899. Dover	C. H. Read, F.S.A.	H. Balfour, W. H. East, Prof. A. C. Haddon, J. L. Myres.
1900. Bradford ...	Prof. John Rhys, M.A..........	Rev. E. Armitage, H. Balfour, W. Crooke, J. L. Myres.
1901. Glasgow ...	Prof. D. J. Cunningham, F.R.S.	W. Crooke, Prof. A. F. Dixon, J. F. Gemmill, J. L. Myres.
1902. Belfast ...	Dr. A. C. Haddon, F.R.S. ...	R. Campbell, Prof. A. F. Dixon, J. L. Myres.
1903. Southport...	Prof. J. Symington, F.R.S. ...	E. N. Fallaize, H. S. Kingsford, E. M. Littler, J. L. Myres.
1904. Cambridge	H. Balfour, M.A.	W. L. H. Duckworth, E. N. Fallaize, H. S. Kingsford, J. L. Myres.
1905. SouthAfrica	Dr. A. C. Haddon, F.R.S. ...	A. R. Brown, A. von Dessauer, E. S. Hartland.
1906. York.........	E. Sidney Hartland, F.S.A....	Dr. G. A. Auden, E. N. Fallaize, H. S. Kingsford, Dr. F. C. Shrubsall.
1907. Leicester ...	D. G. Hogarth, M.A............	C. J. Billson, E. N. Fallaize, H. S. Kingsford, Dr. F. C. Shrubsall.
1908. Dublin	Prof. W. Ridgeway, M.A. ...	E. N. Fallaize, H. S. Kingsford, Dr. F. C. Shrubsall, L. E. Steele.
1909. Winnipeg...	Prof. J. L. Myres, M.A.	H. S. Kingsford, Prof. C. J. Patten, Dr. F. C. Shrubsall.

SECTION I.—PHYSIOLOGY (including Experimental Pathology and Experimental Psychology).

1894. Oxford......	Prof. E. A. Schäfer, F.R.S., M.R.C.S.	Prof. F. Gotch, Dr. J. S. Haldane, M. S. Pembrey.
1896. Liverpool ..	Dr. W. H. Gaskell, F.R.S. ...	Prof. R. Boyce, Prof. C. S. Sherrington.
1897. Toronto ...	Prof. Michael Foster, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington, Dr. L. E. Shore.
1899. Dover	J. N. Langley, F.R.S.	Dr. Howden, Dr. L. E. Shore, Dr. E. H. Starling.
1901. Glasgow ...	Prof. J. G. McKendrick, F.R.S.	W. B. Brodie, W. A. Osborne, Prof. W. H. Thompson.
1902. Belfast ...	Prof. W. D. Halliburton, F.R.S.	J. Barcroft, Dr. W. A. Osborne, Dr. C. Shaw.

Date and Place	Presidents	Secretaries
1904. Cambridge	Prof. C. S. Sherrington, F.R.S.	J. Barcroft, Prof. T. G. Brodie, Dr. L. E. Shore.
1905. SouthAfrica	Col. D. Bruce, C.B., F.R.S. ...	J. Barcroft, Dr. Baumann, Dr. Mackenzie, Dr. G. W. Robertson, Dr. Stanwell.
1906. York.........	Prof. F. Gotch, F.R.S.	J. Barcroft, Dr. J. M. Hamill, Prof. J. S. Macdonald, Dr. D. S. Long.
1907. Leicester ...	Dr. A. D. Waller, F.R.S.	Dr. N. H. Alcock, J. Barcroft, Prof. J. S. Macdonald, Dr. A. Warner.
1908. Dublin	Dr. J. Scott Haldane, F.R.S.	Prof. D J. Coffey, Dr. P. T. Herring, Prof. J. S. Macdonald, Dr. H. E. Roaf.
1909. Winnipeg...	Prof. E. H. Starling, F.R.S....	Dr. N. H. Alcock, Prof. P. T. Herring, Dr. W. Webster.

SECTION K.—BOTANY.

1895. Ipswich ...	W. T. Thiselton-Dyer, F.R.S.	A. C. Seward, Prof. F. E. Weiss.
1896. Liverpool...	Dr. D. H. Scott, F.R.S.	Prof. Harvey Gibson, A. C. Seward, Prof. F. E. Weiss.
1897. Toronto ...	Prof. Marshall Ward, F.R.S.	Prof. J. B. Farmer, E. C. Jeffrey, A. C. Seward, Prof. F. E. Weiss.
1898. Bristol......	Prof. F. O. Bower, F.R.S. ...	A. C. Seward, H. Wager, J. W. White.
1899. Dover	Sir George King, F.R.S.	G. Dowker, A. C. Seward, H. Wager.
1900. Bradford ...	Prof. S. H. Vines, F.R.S.......	A. C. Seward, H. Wager, W. West.
1901. Glasgow ...	Prof. I. B. Balfour, F.R.S. ...	D. T. Gwynne-Vaughan, G. F. Scott-Elliot, A. C. Seward, H. Wager.
1902. Belfast ...	Prof. J. R. Green, F.R.S.......	A. G. Tansley, Rev. C. H. Waddell, H. Wager, R. H. Yapp.
1903. Southport	A. C. Seward, F.R.S.	H. Ball, A. G. Tansley, H. Wager, R. H. Yapp.
1904. Cambridge	Francis Darwin, F.R.S. ...... *Sub-section of Agriculture*—Dr. W. Somerville.	Dr. F. F. Blackman, A. G. Tansley, H. Wager, T. B. Wood, R. H. Yapp.
1905. SouthAfrica	Harold Wager, F.R.S.	R. P. Gregory, Dr. Marloth, Prof. Pearson, Prof. R. H. Yapp.
1906. York.........	Prof. F. W. Oliver, F.R.S. ...	Dr. A. Burtt, R. P. Gregory, Prof. A. G. Tansley, Prof. R. H. Yapp.
1907. Leicester ...	Prof. J. B. Farmer, F.R.S. ...	W. Bell, R. P. Gregory, Prof. A. G. Tansley, Prof. R. H. Yapp.
1908. Dublin	Dr. F. F. Blackman, F.R.S....	Prof. H. H. Dixon, R. P. Gregory, A. G. Tansley, Prof. R. H. Yapp.
1909. Winnipeg...	Lieut.-Col. D. Prain, C.I.E., F.R.S.	Prof. A. H. R. Buller, Prof. D. T. Gwynne-Vaughan, Prof. R. H. Yapp.
	Sub-section of Agriculture—Major P. G. Craigie, C.B.	W. J. Black, Dr. E. J. Russell, Prof. J. Wilson.

SECTION L.—EDUCATIONAL SCIENCE.

1901. Glasgow ...	Sir John E. Gorst, F.R.S. ...	R. A. Gregory, W. M. Heller, R. Y. Howie, C. W. Kimmins, Prof. H. L. Withers.
1902. Belfast ...	Prof. H. E. Armstrong, F.R.S.	Prof. R. A. Gregory, W. M. Heller, R. M. Jones, Dr. C. W. Kimmins, Prof. H. L. Withers.
1903. Southport ..	Sir W. de W. Abney, K.C.B., F.R.S.	Prof. R. A. Gregory, W. M. Heller, Dr. C. W. Kimmins, Dr. H. L. Snape.
904. Cambridge	Bishop of Hereford, D.D. ...	J. H. Flather, Prof. R. A. Gregory, W. M. Heller, Dr. C. W. Kimmins.
1905. SouthAfrica	Prof. Sir R. C. Jebb, D.C.L., M.P.	A. D. Hall, Prof. Hele-Shaw, Dr. C. W. Kimmins, J. R. Whitton.
1906. York.........	Prof. M. E. Sadler, LL.D. ...	Prof. R. A. Gregory, W. M. Heller, Hugh Richardson.

Date and Place	Presidents	Secretaries
1907. Leicester ...	Sir Philip Magnus, M.P.	W. D. Eggar, Prof. R. A. Gregory, J. S. Laver, Hugh Richardson.
1908. Dublin	Prof. L. C. Miall, F.R.S.	Prof. E. P. Culverwell, W. D. Eggar, George Fletcher, Prof. R. A. Gregory, Hugh Richardson.
1909. Winnipeg...	Rev. H. B. Gray, D.D.	W. D. Eggar, R. Fletcher, J. L. Holland, Hugh Richardson.

CHAIRMEN AND SECRETARIES OF THE CONFERENCES OF DELEGATES OF CORRESPONDING SOCIETIES.

Date and Place	Chairmen	Secretaries
1885. Aberdeen...	Francis Galton, F.R.S.........	Prof. Meldola.
1886. Birmingham	Prof. A. W. Williamson, F.R.S.	Prof. Meldola, F.R.S.
1887. Manchester	Prof. W. Boyd Dawkins, F.R.S.	Prof. Meldola, F.R.S.
1888. Bath.........	John Evans, F.R.S.	Prof. Meldola, F.R.S.
1889. Newcastle-upon-Tyne	Francis Galton, F.R.S..........	Prof. G. A. Lebour.
1890. Leeds	G. J. Symons, F.R.S.	Prof. Meldola, F.R.S.
1891. Cardiff	G. J. Symons, F.R.S.	Prof. Meldola, F.R.S.
1892. Edinburgh	Prof. Meldola, F.R.S.	T. V. Holmes.
1893. Nottingham	Dr. J. G. Garson	T. V. Holmes.
1894. Oxford	Prof. Meldola, F.R.S.	T. V. Holmes.
1895. Ipswich ...	G. J. Symons, F.R.S.	T. V. Holmes.
1896. Liverpool...	Dr. J. G. Garson	T. V. Holmes.
1897. Toronto ...	Prof. Meldola, F.R.S.	J. Hopkinson.
1898. Bristol	W. Whitaker, F.R.S.	T. V. Holmes.
1899. Dover	Rev. T. R. R. Stebbing, F.R.S.	T. V. Holmes.
1900. Bradford ...	Prof. E. B. Poulton, F.R.S. ...	T. V. Holmes.
1901. Glasgow ...	F. W. Rudler, F.G.S.	Dr. J. G. Garson, A. Somerville.
1902 Belfast......	Prof. W. W. Watts, F.G.S. ...	E. J. Bles.
1903. Southport ..	W. Whitaker, F.R.S.	F. W. Rudler.
1904. Cambridge	Prof. E. H. Griffiths, F.R.S.	F. W. Rudler.
1905. London ...	Dr. A. Smith Woodward, F.R.S.	F. W. Rudler.
1906. York.........	Sir Edward Brabrook, C.B....	F. W. Rudler.
1907. Leicester ...	H. J. Mackinder, M.A..........	F. W. Rudler, I.S.O.
1908. Dublin	Prof. H. A. Miers, F.R.S.......	W. P. D. Stebbing.
1909. London ...	Dr. A. C. Haddon, F.R.S. ...	W. P. D. Stebbing.

EVENING DISCOURSES.

Date and Place	Lecturers	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S......	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison..................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S..........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson.....................	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.............	The Gigantic Tortoise of the Siwalik Hills in India.

Date and Place	Lecturers	Subject of Discourse
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive Substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its Neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham.	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying Velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connection with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their Changes of Form.
	G. B. Airy, F.R.S., Astronomer Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast......	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent Discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent Discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.............	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of Researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform Research up to the present time.
	W. R. Grove, F.R.S.............	Correlation of Physical Forces.
1857. Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G.B.Airy,F.R.S.,Astron.Royal	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.............	Organic Chemistry.

Date and Place	Lecturers	Subject of Discourse
1863. Newcastle	Prof. Williamson, F.R.S.......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.........	The Balloon Ascents made for the British Association.
1864. Bath.........	Prof. Roscoe, F.R.S.............	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham.	J. Beete Jukes, F.R.S..........	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S.......	The Results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.......	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S.......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of Knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S.............	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S..........	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S. ..	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S.................	Some Recent Investigations and Applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilisation.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast......	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarised Light.
	F. J. Bramwell, F.R.S..........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The 'Challenger' Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S.............	The New Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.............	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S..........	Mental Imagery.
1881. York.........	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S....	The Electric Discharge; its Forms and its Functions.

Date and Place	Lecturers	Subject of Discourse
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport...	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick.	Galvanic and Animal Electricity.
1884. Montreal...	Prof. O. J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.
1885. Aberdeen...	Prof. W. G. Adams, F.R.S. ...	The Electric Light and Atmospheric Absorption.
	John Murray, F.R.S.E..........	The Great Ocean Basins.
1886. Birmingham.	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
	Prof. W. Rutherford, M.D. ...	The Sense of Hearing.
1887. Manchester	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
	Col. Sir F. de Winton	Explorations in Central Africa.
1888. Bath.........	Prof. W. E. Ayrton, F.R.S. ...	The Electrical Transmission of Power.
	Prof. T. G. Bonney, D.Sc., F.R.S.	The Foundation Stones of the Earth's Crust.
1889. Newcastle-upon-Tyne	Prof. W. C. Roberts-Austen, F.R.S.	The Hardening and Tempering of Steel.
	Walter Gardiner, M.A.........	How Plants maintain themselves in the Struggle for Existence.
1890. Leeds	E. B. Poulton, M.A., F.R.S....	Mimicry.
	Prof. C. Vernon Boys, F.R.S.	Quartz Fibres and their Applications.
1891. Cardiff......	Prof. L. C. Miall, F.L.S., F.G.S.	Some Difficulties in the Life of Aquatic Insects.
	Prof. A. W. Rücker, M.A., F.R.S.	Electrical Stress.
1892. Edinburgh	Prof. A. M. Marshall, F.R.S.	Pedigrees.
	Prof. J. A. Ewing, M.A., F.R.S.	Magnetic Induction.
1893. Nottingham	Prof. A. Smithells, B.Sc.	Flame.
	Prof. Victor Horsley, F.R.S.	The Discovery of the Physiology of the Nervous System.
1894. Oxford......	J. W. Gregory, D.Sc., F.G.S.	Experiences and Prospects of African Exploration.
	Prof. J. Shield Nicholson, M.A.	Historical Progress and Ideal Socialism.
1895. Ipswich ...	Prof. S. P. Thompson, F.R.S.	Magnetism in Rotation.
	Prof. Percy F. Frankland, F.R.S.	The Work of Pasteur and its various Developments.
1896. Liverpool...	Dr. F. Elgar, F.R.S.	Safety in Ships.
	Prof. Flinders Petrie, D.C.L.	Man before Writing.
1897. Toronto ...	Prof. W. C. Roberts-Austen, F.R.S.	Canada's Metals.
	J. Milne, F.R.S..................	Earthquakes and Volcanoes.
1898. Bristol......	Prof. W. J. Sollas, F.R.S.	Funafuti: the Study of a Coral Island.
	Herbert Jackson	Phosphorescence.
1899. Dover	Prof. Charles Richet...........	La vibration nerveuse.
	Prof. J. Fleming, F.R.S.	The Centenary of the Electric Current.
1900. Bradford ...	Prof. F. Gotch, F.R.S.	Animal Electricity.
	Prof. W. Stroud.	Range Finders.
1901. Glasgow ...	Prof. W. Ramsay, F.R.S	The Inert Constituents of the Atmosphere.
	Francis Darwin, F.R.S.	The Movements of Plants.
1902. Belfast ...	Prof. J. J. Thomson, F.R.S....	Becquerel Rays and Radio-activity.
	Prof. W. F. R. Weldon, F.R.S.	Inheritance.
1903. Southport...	Dr. R. Munro	Man as Artist and Sportsman in the Palæolithic Period.
	Dr. A. Rowe	The Old Chalk Sea, and some of its Teachings.

Date and Place	Lecturers	Subject of Discourse
1904. Cambridge	Prof. G. H. Darwin, F.R.S....	Ripple-Marks and Sand-Dunes.
	Prof. H. F. Osborn	Palæontological Discoveries in the Rocky Mountains.
1905. South Africa:		
Cape Town ...	Prof. E. B. Poulton, F.R.S. ...	W. J. Burchell's Discoveries in South Africa.
	C. Vernon Boys, F.R.S.	Some Surface Actions of Fluids.
Durban ...	Douglas W. Freshfield.........	The Mountains of the Old World.
	Prof. W. A. Herdman, F.R.S.	Marine Biology.
Pietermaritzburg.	Col. D. Bruce, C.B., F.R.S....	Sleeping Sickness.
	H. T. Ferrar	The Cruise of the 'Discovery.'
Johannesburg	Prof. W. E. Ayrton, F.R.S....	The Distribution of Power.
	Prof. J. O. Arnold...............	Steel as an Igneous Rock.
Pretoria ...	A. E. Shipley, F.R.S.	Fly-borne Diseases: Malaria, Sleeping Sickness, &c.
Bloemfontein...	A. R. Hinks	The Milky Way and the Clouds of Magellan.
Kimberley ...	Sir Wm. Crookes, F.R.S.	Diamonds.
	Prof. J. B. Porter	The Bearing of Engineering on Mining.
Bulawayo ...	D. Randall-MacIver	The Ruins of Rhodesia.
1906. York.........	Dr. Tempest Anderson.........	Volcanoes.
	Dr. A. D. Waller, F.R.S.	The Electrical Signs of Life, and their Abolition by Chloroform.
1907. Leicester...	W. Duddell, F.R.S.	The Ark and the Spark in Radio-telegraphy.
	Dr. F. A. Dixey..................	Recent Developments in the Theory of Mimicry.
1908. Dublin	Prof. H. H. Turner, F.R.S. ...	Halley's Comet.
	Prof. W. M. Davis.	The Lessons of the Colorado Canyon.
1909. Winnipeg...	Dr. A. E. H. Tutton, F.R.S....	The Seven Styles of Crystal Architecture.
	Prof. W. A. Herdman, F.R.S.	Our Food from the Waters.
	[1] Prof. H. B. Dixon, F.R.S....	The Chemistry of Flame.
	[1] Prof. J. H. Poynting, F.R.S.	The Pressure of Light.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturers	Subject of Lecture
1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	The modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool...	Sir John Lubbock, Bart., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S............	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B....	A Journey through Africa.
1877. Plymouth...	W. H. Preece.....................	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.

[1] 'Popular Lectures,' delivered to the citizens of Winnipeg.

Date and Place	Lecturers	Subject of Lecture
1881. York	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snowflakes.
1882. Southampton.	John Evans, D.C.L., Treas. R.S.	Unwritten History, and how to read it.
1883. Southpo t...	Sir F. J. Bramwell, F.R.S. ...	Talking by Electricity—Telephones.
1884. Montreal ...	Prof. R. S. Ball, F.R.S..........	Comets.
1885. Aberdeen ...	H. B. Dixon, M.A.	The Nature of Explosions.
1886. Birmingham	Prof. W. C. Roberts-Austen, F.R.S.	The Colours of Metals and their Alloys.
1887. Manchester	Prof. G. Forbes, F.R.S.	Electric Lighting.
1888. Bath	Sir John Lubbock, Bart., F.R.S.	The Customs of Savage Races.
1889. Newcastle-upon-Tyne	B. Baker, M.Inst.C.E.	The Forth Bridge.
1890. Leeds	Prof. J. Perry, D.Sc., F.R.S.	Spinning Tops.
1891. Cardiff	Prof. S. P. Thompson, F.R.S.	Electricity in Mining.
1892. Edinburgh..	Prof. C. Vernon Boys, F.R.S.	Electric Spark Photographs.
1893. Nottingham	Prof. Vivian B. Lewes	Spontaneous Combustion.
1894. Oxford	Prof. W. J. Sollas, F.R.S. ...	Geologies and Deluges.
1895. Ipswich ...	Dr. A. H. Fison..................	Colour.
1896. Liverpool...	Prof. J. A. Fleming, F.R.S....	The Earth a Great Magnet.
1897. Toronto ...	Dr. H. O. Forbes	New Guinea.
1898. Bristol	Prof. E. B. Poulton, F.R.S. ...	The ways in which Animals Warn their Enemies and Signal to their Friends.
1900. Bradford ...	Prof. S. P. Thompson, F.R.S.	Electricity in the Industries.
1901. Glasgow ...	H. J. Mackinder, M.A..........	The Movements of Men by Land and Sea.
1902. Belfast......	Prof. L. C. Miall, F.R.S.	Gnats and Mosquitoes.
1903. Southport...	Dr. J. S. Flett	Martinique and St. Vincent: the Eruptions of 1902.
1904. Cambridge..	Dr. J. E. Marr, F.R.S.	The Forms of Mountains.
1906. York.........	Prof. S. P. Thompson, F.R.S.	The Manufacture of Light.
1907. Leicester ...	Prof. H. A. Miers, F.R.S.......	The Growth of a Crystal.
1908. Dublin	Dr. A. E. H. Tutton, F.R.S.	The Crystallisation of Water.

Table showing the Attendances and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	Viscount Milton, D.C.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S.	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S.	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres. R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D., F.R.S.	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec.R.S.	296	20
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S.	267	13
1901, Sept. 11	Glasgow	Prof. A. W. Rücker, D.Sc., Sec.R.S.	310	37
1902, Sept. 10	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17	Cambridge	Rt. Hon. A. J. Balfour, M.P., F.R.S.	419	32
1905, Aug. 15	South Africa	Prof. G. H. Darwin, LL.D., F.R.S.	115	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19
1908, Sept. 2	Dublin	Dr. Francis Darwin, F.R.S.	294	24
1909, Aug. 25	Winnipeg	Prof. Sir J. J. Thomson, F.R.S.	117	13

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.
¶ Including 848 Members of the South African Association.

at Annual Meetings of the Association.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899
297	45	801	482	9	1915	1801 0 0	1072 10 0	1900
374	131	794	246	20	1912	2046 0 0	945 0 0	1901
314	86	647	305	6	1620	1644 0 0	947 0 0	1902
319	90	688	365	21	1754	1762 0 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0 0	887 18 11	1904
937¶	411	430	181	16	2130	2422 0 0	928 2 2	1905
356	93	817	352	22	1972	1811 0 0	882 0 9	1906
339	61	659	251	42	1647	1561 0 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0 0	1157 18 8	1908
290**	162	789	90	7	1468	1623 0 0	1014 9 9	1909

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.
** Including 137 Members of the American Association.

ANALYSIS OF ATTENDANCES AT THE ANNUAL MEETINGS, 1831–1906.

[*The total attendances for the years* 1832, 1835, 1843, *and* 1844 *are unknown.*]

Average attendance at 72 *Meetings* : 1855.

	Average Attendance
Average attendance at 5 Meetings beginning during *June, between* 1833 *and* 1860	1260
Average attendance at 3 Meetings beginning during *July, between* 1841 *and* 1851	947
Average attendance at 28 Meetings beginning during *August, between* 1836 *and* 1906	1978 [1]
Average attendance at 34 Meetings beginning during *September, between* 1831 *and* 1903	1933
Attendance at 1 Meeting held in *October, Cambridge*, 1862	1161

Meetings beginning during August and September.

Average attendance at—

4 Meetings beginning during the 1st week in *August* (1st– 7th)	1905
5 ,, ,, ,, ,, 2nd ,, ,, ,, (8th–14th)	2130
8 ,, ,, ,, ,, 3rd ,, ,, ,, (15th–21st)	1761
11 ,, ,, ,, ,, 4th ,, ,, ,, (22nd–31st)	2094

Average attendance at—

11 Meetings beginning during the 1st week in *September* (1st– 7th)	2082
16 ,, ,, ,, ,, 2nd ,, ,, ,, (8th–14th)	1860
5 ,, ,, ,, ,, 3rd ,, ,, ,, (15th–21st)	2206
2 ,, ,, ,, ,, 4th ,, ,, ,, (22nd–30th)	1025

Meetings beginning during June, July, and October.

Attendance at 1 Meeting (1845, June 19) beginning during the 3rd week in *June* (15th–21st)	1079
Average attendance at 4 Meetings beginning during the 4th week in *June* (22nd–30th)	1306
Attendance at 1 Meeting (1851, July 2) beginning during the 1st week in *July* (1st–7th)	710
Average attendance at 2 Meetings beginning during the 3rd week in *July* (15th–21st)	1066
Attendance at 1 Meeting (1862, October 1) beginning during the 1st week in *October* (1st–7th)	1161

[1] Average attendance at 29 Meetings, *including* South Africa, 1905 (August 15–September 1): 1983.

[2] Average attendance at 9 Meetings, *including* South Africa, 1905 (August 15–September 1): 1802.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes.

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

	£	s.	d.
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0

1836.

	£	s.	d.
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on Long-continued Heat	17	1	0
Rain-gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0

1837.

	£	s.	d.
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6

1838.

	£	s.	d.
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer Construction	100	0	0
Strength of Cast Iron	60	0	0
Preservation of Animal and Vegetable Substances	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2

1839.

	£	s.	d.
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	0
Cast-iron Experiments	103	0	7
Railway Constants	28	7	0
Land and Sea Level	274	1	2
Steam-vessels' Engines	100	0	4
Stars in Histoire Céleste	171	18	0
Stars (Lacaille)	11	0	6
Stars in R.A.S. Catalogue	166	16	0
Animal Secretions	10	10	6
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0

1840.

	£	s.	d.
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4

1841.

	£	s.	d.
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Firth of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8

	£	s.	d.
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland ...	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment at Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells......	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology 1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument.........1842	10	3	6
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh..................	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment at Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces ...	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall...	10	0	0
Physiological Action of Medicines..............................	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory...	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain ...	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining the Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

1851.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.

	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854......£ 75 0 0; 1855......£500 0 0	575	0	0

	£	s.	d.
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seed	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahagow	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland Coasts	25	0	0
Connection of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east Coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee Superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
Electrical Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging, Shetland	75	0	0
Dredging, Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-gauges	19	15	8
Cast-iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee............	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-bed ...	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation ...	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards............	100	0	0
Malta Caves Exploration......	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall................	25	0	0
DredgingAberdeenshireCoast	25	0	0
Dredging Hebrides Coast ...	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	29	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches ...	30	0	0
Palestine Exploration Fund...	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Meteorological Instruments, Palestine........................	50	0	0
Lunar Committee	120	0	0
Metrical Committee............	30	0	0
Kent's Hole Explorations ...	100	0	0
Palestine Explorations.........	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall..................	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-bed ...	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards............	100	0	0
Ethyl and Methyl Series......	25	0	0
Fossil Crustacea.................	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds.	100	0	0
Iron and Steel Manufacture...	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment at Kew Observatory....	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record...............	100	0	0
Kent's Hole Explorations......	150	0	0
Steamship Performances	100	0	0
British Rainfall..................	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl Series.....................	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks.....................	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall..	30	0	0
British Fossil Carols............	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature ...	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	50	0	0
Metrical Committee............	25	0	0
Zoological Record...............	100	0	0
Committee on Gases in Deep-well Water.....................	25	0	0
British Rainfall..................	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations......	150	0	0
Steamship Performances......	30	0	0
Chemical Constitution of Cast Iron........................	80	0	0
Iron and Steel Manufacture...	100	0	0
Methyl Series.....................	30	0	0
Organic Remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals............	50	0	0
Bagshot Leaf-beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature ...	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids.....................	12	0	0
Kiltorcan Fossils	20	0	0

	£	s.	d.
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observation	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorology	100	0	0
Magnetisation of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone Corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Elliptic Functions	100	0	0
Magnetisation of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0
Specific Volume of Liquids	25	0	0
Estimation of Potash and Phosphoric Acid	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations	100	0	0
Kent's Cavern Exploration	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record	100	0	0
Instructions for Travellers	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall	100	0	0
Ohm's Law	9	15	0
Tide Calculating Machine	200	0	0
Specific Volume of Liquids	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	5	0	0
Estimation of Potash and Phosphoric Acid	13	0	0
Exploration of Victoria Cave	100	0	0
Geological Record	100	0	0
Kent's Cavern Exploration	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland	1	10	0
Zoological Record	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Naples Zoological Station	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles	13	15	0
Measuring Speed of Ships	10	0	0
Effect of Propeller on turning of Steam-vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acid in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpeæ, Report on	20	0	0
Mechanical Equivalent of Heat	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperature	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	10	0	0
British Earthworks	25	0	0
Atmospheric Electricity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid	1	18	0
Geological Record	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c.	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves...	100	0	0
Geological Record...............	100	0	0
Investigation of Pulse Phenomena by means of Siphon Recorder..........................	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters..........................	15	0	0
Transmission of Electrical Impulses through Nerve Structure..........................	30	0	0
Calculation of Factor Table for Fourth Million	100	0	0
Anthropometric Committee...	66	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record................	100	0	0
Fermanagh Caves Exploration............................	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors................	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland ...	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature..............................	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration ...	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts...............	25	0	0
Anthropometric Committee...	50	0	0
Natural History of Socotra ...	100	0	0
Calculation of Factor Tables for 5th and 6th Millions ...	150	0	0
Underground Waters...........	10	0	0
Steering of Screw Steamers...	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum.........	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature ...	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum.........	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration ...	50	0	0
Geological Record...............	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature..	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico......	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature ...	20	0	0
Electrical Standards	25	0	0
High Insulation Key	5	0	0
Tidal Observations	10	0	0
Specific Refractions	7	3	1
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station ...	50	0	0
Naples Zoological Station ...	75	0	0
Natural History of Socotra ...	50	0	0
Anthropological Notes and Queries	9	0	0
Zoological Record	100	0	0
Weights and Heights of Human Beings	30	0	0
	£476	3	1

1882.

	£	s.	d.
Exploration of Central Africa	100	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Standards for Electrical Measurements	100	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements	50	0	0
Photographing Ultra-violet Spark Spectra	25	0	0
Geological Record	100	0	0
Earthquake Phenomena of Japan	25	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Fossil Plants of Halifax	15	0	0
Geological Map of Europe ...	25	0	0
Circulation of Underground Waters	15	0	0
Tertiary Flora of North of Ireland	20	0	0
British Polyzoa	10	0	0
Exploration of Caves of South of Ireland	10	0	0
Exploration of Raygill Fissure	20	0	0
Naples Zoological Station ...	80	0	0
Albuminoid Substances of Serum	10	0	0
Elimination of Nitrogen by Bodily Exercise	50	0	0
Migration of Birds	15	0	0
Natural History of Socotra ...	100	0	0
Natural History of Timor-laut	100	0	0
Record of Zoological Literature	100	0	0
Anthropometric Committee...	50	0	0
	£1126	1	11

1883.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Isomeric Naphthalene Derivatives	15	0	0
Earthquake Phenomena of Japan	50	0	0
Fossil Plants of Halifax	20	0	0
British Fossil Polyzoa	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Circulation of Underground Waters	15	0	0
Geological Record	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Zoological Literature Record	100	0	0
Migration of Birds	20	0	0
Zoological Station at Naples	80	0	0
Scottish Zoological Station ...	25	0	0
Elimination of Nitrogen by Bodily Exercise	38	3	3
Exploration of Mount Kilima-njaro	500	0	0
Investigation of Loughton Camp	10	0	0
Natural History of Timor-laut	50	0	0
Screw Gauges	5	0	0
	£1083	3	3

1884.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Collecting and Investigating Meteoric Dust	20	0	0
Meteorological Observatory at Chepstow	25	0	0
Tidal Observations	10	0	0
Ultra Violet Spark Spectra ...	8	4	0
Earthquake Phenomena of Japan	75	0	0
Fossil Plants of Halifax	15	0	0
Fossil Polyzoa	10	0	0
Erratic Blocks of England ...	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Circulation of Underground Waters	5	0	0
International Geological Map	20	0	0
Bibliography of Groups of Invertebrata	50	0	0
Natural History of Timor-laut	50	0	0
Naples Zoological Station ...	80	0	0
Exploration of Mount Kilima-njaro, East Africa	500	0	0
Migration of Birds	20	0	0
Coagulation of Blood	100	0	0
Zoological Literature Record	100	0	0
Anthropometric Committee...	10	0	0
	£1173	4	0

1885.

	£	s.	d.
Synoptic Chart of Indian Ocean	50	0	0
Reduction of Tidal Observations	10	0	0
Calculating Tables in Theory of Numbers	100	0	0
Meteorological Observations on Ben Nevis	50	0	0
Meteoric Dust	70	0	0
Vapour Pressures, &c., of Salt Solutions	25	0	0
Physical Constants of Solutions	20	0	0
Volcanic Phenomena of Vesuvius	25	0	0
Raygill Fissure	15	0	0
Earthquake Phenomena of Japan	70	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Fossil Plants of British Tertiary and Secondary Beds	50	0	0
Geological Record	50	0	0
Circulation of Underground Waters	10	0	0
Naples Zoological Station	100	0	0
Zoological Literature Record	100	0	0
Migration of Birds	30	0	0
Exploration of Mount Kilimanjaro	25	0	0
Recent Polyzoa	10	0	0
Granton Biological Station	100	0	0
Biological Stations on Coasts of United Kingdom	150	0	0
Exploration of New Guinea	200	0	0
Exploration of Mount Roraima	100	0	0
	£1385	0	0

1886.

	£	s.	d.
Electrical Standards	40	0	0
Solar Radiation	9	10	6
Tidal Observations	50	0	0
Magnetic Observations	10	10	0
Observations on Ben Nevis	100	0	0
Physical and Chemical Bearings of Electrolysis	20	0	0
Chemical Nomenclature	5	0	0
Fossil Plants of British Tertiary and Secondary Beds	20	0	0
Caves in North Wales	25	0	0
Volcanic Phenomena of Vesuvius	30	0	0
Geological Record	100	0	0
Palæozoic Phyllopoda	15	0	0
Zoological Literature Record	100	0	0
Granton Biological Station	75	0	0
Naples Zoological Station	50	0	0
Researches in Food-Fishes and Invertebrata at St. Andrews	75	0	0
Migration of Birds	30	0	0
Secretion of Urine	10	0	0
Exploration of New Guinea	150	0	0
Regulation of Wages under Sliding Scales	10	0	0
Prehistoric Race in Greek Islands	20	0	0
North-Western Tribes of Canada	50	0	0
	£995	0	6

1887.

	£	s.	d.
Solar Radiation	18	10	0
Electrolysis	30	0	0
Ben Nevis Observatory	75	0	0
Standards of Light (1886 grant)	20	0	0
Standards of Light (1887 grant)	10	0	0
Harmonic Analysis of Tidal Observations	15	0	0
Magnetic Observations	26	2	0
Electrical Standards	50	0	0
Silent Discharge of Electricity	20	0	0
Absorption Spectra	40	0	0
Nature of Solution	20	0	0
Influence of Silicon on Steel	30	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Volcanic Phenomena of Japan (1886 grant)	50	0	0
Volcanic Phenomena of Japan (1887 grant)	50	0	0
Cae Gwyn Cave, N. Wales	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	20	0	0
Coal Plants of Halifax	25	0	0
Microscopic Structure of the Rocks of Anglesey	10	0	0
Exploration of the Eocene Beds of the Isle of Wight	20	0	0
Underground Waters	5	0	0
'Manure' Gravels of Wexford	10	0	0
Provincial Museums Reports	5	0	0
Lymphatic System	25	0	0
Naples Biological Station	100	0	0
Plymouth Biological Station	50	0	0
Granton Biological Station	75	0	0
Zoological Record	100	0	0
Flora of China	75	0	0
Flora and Fauna of the Cameroons	75	0	0
Migration of Birds	30	0	0
Bathy-hypsographical Map of British Isles	7	6	0
Regulation of Wages	10	0	0
Prehistoric Race of Greek Islands	20	0	0
Racial Photographs, Egyptian	20	0	0
	£1186	18	0

1888.

	£	s.	d.
Ben Nevis Observatory	150	0	0
Electrical Standards	2	6	4
Magnetic Observations	15	0	0
Standards of Light	79	2	3
Electrolysis	30	0	0
Uniform Nomenclature in Mechanics	10	0	0
Silent Discharge of Electricity	9	11	10
Properties of Solutions	25	0	0
Influence of Silicon on Steel	20	0	0
Methods of Teaching Chemistry	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Action of Light on Hydracids	20	0	0
Sea Beach near Bridlington	20	0	0
Geological Record	50	0	0
Manure Gravels of Wexford	10	0	0
Erosion of Sea Coasts	10	0	0
Underground Waters	5	0	0
Palæontographical Society	50	0	0
Pliocene Fauna of St. Erth	50	0	0
Carboniferous Flora of Lancashire and West Yorkshire	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Zoology and Botany of West Indies	100	0	0
Flora of Bahamas	100	0	0
Development of Fishes—St. Andrews	50	0	0
Marine Laboratory, Plymouth	100	0	0
Migration of Birds	30	0	0
Flora of China	75	0	0
Naples Zoological Station	100	0	0
Lymphatic System	25	0	0
Biological Station at Granton	50	0	0
Peradeniya Botanical Station	50	0	0
Development of Teleostei	15	0	0
Depth of Frozen Soil in Polar Regions	5	0	0
Precious Metals in Circulation	20	0	0
Value of Monetary Standard	10	0	0
Effect of Occupations on Physical Development	25	0	0
North-Western Tribes of Canada	100	0	0
Prehistoric Race in Greek Islands	20	0	0
	£1511	0	5

1889.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	75	0	0
Electrolysis	20	0	0
Surface Water Temperature	30	0	0
Silent Discharge of Electricity on Oxygen	6	4	8
Methods of teaching Chemistry	10	0	0
Action of Light on Hydracids	10	0	0
Geological Record	80	0	0
Volcanic Phenomena of Japan	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	20	0	0
Higher Eocene Beds of Isle of Wight	15	0	0
West Indian Explorations	100	0	0
Flora of China	25	0	0
Naples Zoological Station	100	0	0
Physiology of Lymphatic System	25	0	0
Experiments with a Tow-net	5	16	3
Natural History of Friendly Islands	100	0	0
Geology and Geography of Atlas Range	100	0	0
Action of Waves and Currents in Estuaries	100	0	0
North-Western Tribes of Canada	150	0	0
Nomad Tribes of Asia Minor	30	0	0
Corresponding Societies	20	0	0
Marine Biological Association	200	0	0
'Baths Committee,' Bath	100	0	0
	£1417	0	11

1890.

	£	s.	d.
Electrical Standards	12	17	0
Electrolysis	5	0	0
Electro-optics	50	0	0
Mathematical Tables	25	0	0
Volcanic and Seismological Phenomena of Japan	75	0	0
Pellian Equation Tables	15	0	0
Properties of Solutions	10	0	0
International Standard for the Analysis of Iron and Steel	10	0	0
Influence of the Silent Discharge of Electricity on Oxygen	5	0	0
Methods of teaching Chemistry	10	0	0
Recording Results of Water Analysis	4	1	0
Oxidation of Hydracids in Sunlight	15	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	10	0	0
Circulation of Underground Waters	5	0	0
Excavations at Oldbury Hill	15	0	0
Cretaceous Polyzoa	10	0	0
Geological Photographs	7	14	11
Lias Beds of Northampton	25	0	0
Botanical Station at Peradeniya	25	0	0

	£	s.	d.
Experiments with a Tow-net	4	3	9
Naples Zoological Station ...	100	0	0
Zoology and Botany of the West India Islands	100	0	0
Marine Biological Association	30	0	0
Action of Waves and Currents in Estuaries	150	0	0
Graphic Methods in Mechanical Science	11	0	0
Anthropometric Calculations	5	0	0
Nomad Tribes of Asia Minor	25	0	0
Corresponding Societies	20	0	0
	£799	16	8

1891.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	100	0	0
Electrolysis	5	0	0
Seismological Phenomena of Japan	10	0	0
Temperatures of Lakes	20	0	0
Photographs of Meteorological Phenomena	5	0	0
Discharge of Electricity from Points	10	0	0
Ultra Violet Rays of Solar Spectrum	50	0	0
International Standard for Analysis of Iron and Steel...	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Formation of Haloids	25	0	0
Action of Light on Dyes	17	10	0
Geological Record	100	0	0
Volcanic Phenomena of Vesuvius	10	0	0
Fossil Phyllopoda	10	0	0
Photographs of Geological Interest	9	5	0
Lias of Northamptonshire ...	25	0	0
Registration of Type-Specimens of British Fossils	5	5	0
Investigation of Elbolton Cave	25	0	0
Botanical Station at Peradeniya	50	0	0
Experiments with a Tow-net	40	0	0
Marine Biological Association	12	10	0
Disappearance of Native Plants	5	0	0
Action of Waves and Currents in Estuaries	125	0	0
Anthropometric Calculations	10	0	0
New Edition of 'Anthropological Notes and Queries'	50	0	0
North-Western Tribes of Canada	200	0	0
Corresponding Societies	25	0	0
	£1029	10	0

1892.

	£	s.	d.
Observations on Ben Nevis ...	50	0	0
Photographs of Meteorological Phenomena	15	0	0
Pellian Equation Tables	10	0	0
Discharge of Electricity from Points	50	0	0
Seismological Phenomena of Japan	10	0	0
Formation of Haloids	12	0	0
Properties of Solutions	10	0	0
Action of Light on Dyed Colours	10	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	20	0	0
Underground Waters	10	0	0
Investigation of Elbolton Cave	25	0	0
Excavations at Oldbury Hill	10	0	0
Cretaceous Polyzoa	10	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	17	10	0
Deep-sea Tow-net	40	0	0
Fauna of Sandwich Islands...	100	0	0
Zoology and Botany of West India Islands	100	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Anthropometric Laboratory...	5	0	0
Anthropological Notes and Queries	20	0	0
Prehistoric Remains in Mashonaland	50	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	25	0	0
	£864	10	0

1893.

	£	s.	d.
Electrical Standards	25	0	0
Observations on Ben Nevis ...	150	0	0
Mathematical Tables	15	0	0
Intensity of Solar Radiation	2	8	6
Magnetic Work at the Falmouth Observatory	25	0	0
Isomeric Naphthalene Derivatives	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	5	0	0
Underground Waters	5	0	0
Shell-bearing Deposits at Clava, Chapelhall, &c.	20	0	0
Eurypterids of the Pentland Hills	10	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	30	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	50	0	0

	£	s.	d.
Exploration of Irish Sea	30	0	0
Physiological Action of Oxygen in Asphyxia	20	0	0
Index of Genera and Species of Animals	20	0	0
Exploration of Karakoram Mountains	50	0	0
Scottish Place-names	7	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Economic Training	3	7	0
Anthropometric Laboratory...	5	0	0
Exploration in Abyssinia	25	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	30	0	0
	£907	15	6

1894.

	£	s.	d.
Electrical Standards............	25	0	0
Photographs of Meteorological Phenomena........................	10	0	0
Tables of Mathematical Functions	15	0	0
Intensity of Solar Radiation	5	5	6
Wave-length Tables	10	0	0
Action of Light upon Dyed Colours	5	0	0
Erratic Blocks	15	0	0
Fossil Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	20	0	0
Eurypterids of the Pentland Hills................................	5	0	0
New Sections of Stonesfield Slate	14	0	0
Observations on Earth Tremors	50	0	0
Exploration of Calf-Hole Cave.....	5	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	5	0	0
Zoology of the Sandwich Islands	100	0	0
Zoology of the Irish Sea	40	0	0
Structure and Function of the Mammalian Heart............	10	0	0
Exploration in Abyssinia	30	0	0
Economic Training	9	10	0
Anthropometric Laboratory Statistics........................	5	0	0
Ethnographical Survey	10	0	0
The Lake Village at Glastonbury..............................	40	0	0
Anthropometrical Measurements in Schools	5	0	0
Mental and Physical Condition of Children...............	20	0	0
Corresponding Societies	25	0	0
	£583	15	6

1895.

	£	s.	d.
Electrical Standards............	5	0	0
Photographs of Meteorological Phenomena.....................	10	0	0
Earth Tremors	75	0	0
Abstracts of Physical Papers	100	0	0
Reduction of Magnetic Observations made at Falmouth Observatory	50	0	0
Comparison of Magnetic Standards	25	0	0
Meteorological Observations on Ben Nevis	50	0	0
Wave-length Tables of the Spectra of the Elements ...	10	0	0
Action of Light upon Dyed Colours	4	6	1
Formation of Haloids from Pure Materials	20	0	0
Isomeric Naphthalene Derivatives..........................	30	0	0
Electrolytic Quantitative Analysis	30	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Photographs of Geological Interest	10	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills.....	3	0	0
New Sections of Stonesfield Slate	50	0	0
Exploration of Calf Hole Cave	10	0	0
Nature and Probable Age of High-level Flint-drifts	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea...............	35	9	4
Zoology and Botany of the West India Islands	50	0	0
Index of Genera and Species of Animals	50	0	0
Climatology of Tropical Africa	5	0	0
Exploration of Hadramut ...	50	0	0
Calibration and Comparison of Measuring Instruments ...	25	0	0
Anthropometric Measurements in Schools	5	0	0
Lake Village at Glastonbury	30	0	0
Exploration of a Kitchen-midden at Hastings	10	0	0
Ethnographical Survey	10	0	0
Physiological Applications of the Phonograph...............	25	0	0
Corresponding Societies	30	0	0
	£977	15	5

1896.

	£	s.	d.
Photographs of Meteorological Phenomena	15	0	0
Seismological Observations	80	0	0
Abstracts of Physical Papers	100	0	0
Calculation of certain Integrals	10	0	0
Uniformity of Size of Pages of Transactions, &c.	5	0	0
Wave-length Tables of the Spectra of the Elements	10	0	0
Action of Light upon Dyed Colours	2	6	1
Electrolytic Quantitative Analysis	10	0	0
The Carbohydrates of Barley Straw	50	0	0
Reprinting Discussion on the Relation of Agriculture to Science	5	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills	2	0	0
Investigation of a Coral Reef by Boring and Sounding	10	0	0
Examination of Locality where the Cetiosaurus in the Oxford Museum was found	25	0	0
Palæolithic Deposits at Hoxne	25	0	0
Fauna of Singapore Caves	40	0	0
Age and Relation of Rocks near Moreseat, Aberdeen	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea	50	0	0
Zoology of the Sandwich Islands	100	0	0
African Lake Fauna	100	0	0
Oysters under Normal and Abnormal Environment	40	0	0
Climatology of Tropical Africa	10	0	0
Calibration and Comparison of Measuring Instruments	20	0	0
Small Screw Gauge	10	0	0
North-Western Tribes of Canada	100	0	0
Lake Village at Glastonbury	30	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Physiological Applications of the Phonograph	25	0	0
Corresponding Societies Committee	30	0	0
	£1104	6	1

1897.

	£	s.	d.
Mathematical Tables	25	0	0
Seismological Observations	100	0	0
Abstracts of Physical Papers	100	0	0
Calculation of certain Integrals	10	0	0
Electrolysis and Electrochemistry	50	0	0
Electrolytic Quantitative Analysis	10	0	0
Isomeric Naphthalene Derivatives	50	0	0
Erratic Blocks	10	0	0
Photographs of Geological Interest	15	0	0
Remains of the Irish Elk in the Isle of Man	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	9	10	8
Zoological Bibliography and Publication	5	0	0
Index Generum et Specierum Animalium	100	0	0
Zoology and Botany of the West India Islands	40	0	0
The Details of Observations on the Migration of Birds	40	0	0
Climatology of Tropical Africa	20	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Silchester Excavation	20	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	180	0	0
Oysters and Typhoid	30	0	0
Physiological Applications of the Phonograph	15	0	0
Physiological Effects of Peptone and its Precursors	20	0	0
Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies Committee	25	0	0
	£1059	10	8

1898.

	£	s.	d.
Electrical Standards	75	0	0
Seismological Observations	75	0	0
Abstracts of Physical Papers	100	0	0
Calculation of certain Integrals	10	0	0
Electrolysis and Electro-chemistry	35	0	0
Meteorological Observatory at Montreal	50	0	0

	£	s.	d.
Wave-length Tables of the Spectra of the Elements ...	20	0	0
Action of Light upon Dyed Colours ...	8	0	0
Erratic Blocks ...	5	0	0
Investigation of a Coral Reef	40	0	0
Photographs of Geological Interest ...	10	0	0
Life-zones in British Carboniferous Rocks ...	15	0	0
Pleistocene Fauna and Flora in Canada ...	20	0	0
Table at the Zoological Station, Naples ...	100	0	0
Table at the Biological Laboratory, Plymouth ...	14	0	0
Index Generum et Specierum Animalium ...	100	0	0
Healthy and Unhealthy Oysters ...	30	0	0
Climatology of Tropical Africa	10	0	0
State Monopolies in other Countries ...	15	0	0
Small Screw Gauge ...	20	0	0
North-Western Tribes of Canada...	75	0	0
Lake Village at Glastonbury	37	10	0
Silchester Excavation ...	7	10	0
Ethnological Survey of Canada	75	0	0
Anthropology and Natural History of Torres Straits...	125	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	100	0	0
Fertilisation in Phæophyceæ	15	0	0
Corresponding Societies Committee ...	25	0	0
	£1212	0	0

1899.

	£	s.	d.
Electrical Standards...	225	0	0
Seismological Observations...	65	14	8
Science Abstracts ...	100	0	0
Heat of Combination of Metals in Alloys ...	20	0	0
Radiation in a Magnetic Field	50	0	0
Calculation of certain Integrals ...	10	0	0
Action of Light upon Dyed Colours ...	4	19	6
Relation between Absorption Spectra and Constitution of Organic Substances ...	50	0	0
Erratic Blocks ...	15	0	0
Photographs of Geological Interest ...	10	0	0
Remains of Irish Elk in the Isle of Man...	15	0	0
Pleistocene Flora and Fauna in Canada ...	30	0	0
Records of Disappearing Drift Section at Moel Tryfaen ...	5	0	0
Ty Newydd Caves...	40	0	0
Ossiferous Caves at Uphill ...	30	0	0
Table at the Zoological Station, Naples ...	100	0	0
Table at the Biological Laboratory, Plymouth ...	20	0	0
Index Generum et Specierum Animalium...	100	0	0
Migration of Birds ...	15	0	0
Apparatus for Keeping Aquatic Organisms under Definite Physical Conditions ...	15	0	0
Plankton and Physical Conditions of the English Channel during 1899...	100	0	0
Exploration of Sokotra ...	35	0	0
Lake Village at Glastonbury	50	0	0
Silchester Excavation ...	10	0	0
Ethnological Survey of Canada	35	0	0
New Edition of 'Anthropological Notes and Queries'	40	0	0
Age of Stone Circles...	20	0	0
Physiological Effects of Peptone...	30	0	0
Electrical Changes accompanying Discharge of Respiratory Centres ...	20	0	0
Influence of Drugs upon the Vascular Nervous System...	10	0	0
Histological Changes in Nerve Cells...	20	0	0
Micro-chemistry of Cells ...	40	0	0
Histology of Suprarenal Capsules ...	20	0	0
Comparative Histology of Cerebral Cortex...	10	0	0
Fertilisation in Phæophyceæ	20	0	0
Assimilation in Plants...	20	0	0
Zoological and Botanical Publication ...	5	0	0
Corresponding Societies Committee ...	25	0	0
	£1430	14	2

1900.

	£	s.	d.
Electrical Standards...	25	0	0
Seismological Observations...	60	0	0
Radiation in a Magnetic Field	25	0	0
Meteorological Observatory at Montreal...	20	0	0
Tables of Mathematical Functions ...	75	0	0
Relation between Absorption Spectra and Constitution of Organic Bodies...	30	0	0
Wave-length Tables...	5	0	0
Electrolytic Quantitative Analysis...	5	0	0

	£	s.	d.
Isomorphous Sulphonic Derivatives of Benzene.........	20	0	0
The Nature of Alloys	30	0	0
Photographs of Geological Interest	10	0	0
Remains of Elk in the Isle of Man	5	0	0
Pleistocene Fauna and Flora in Canada	10	0	0
Movements of Underground Waters of Craven	40	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium	50	0	0
Migration of Birds	15	0	0
Plankton and Physical Conditions of the English Channel	40	0	0
Zoology of the Sandwich Islands	100	0	0
Coral Reefs of the Indian Region	30	0	0
Physical and Chemical Constants of Sea-Water	100	0	0
Future Dealings in Raw Produce	2	10	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	50	0	0
New Edition of 'Anthropological Notes and Queries'	40	0	0
Photographs of Anthropological Interest	10	0	0
Mental and Physical Condition of Children in Schools	5	0	0
Ethnography of the Malay Peninsula	25	0	0
Physiological Effects of Peptone	20	0	0
Comparative Histology of Suprarenal Capsules.........	20	0	0
Comparative Histology of Cerebral Cortex...............	5	0	0
Electrical Changes in Mammalian Nerves	20	0	0
Vascular Supply of Secreting Glands...........................	10	0	0
Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies Committee	20	0	0
	£1072	10	0

1901.

	£	s.	d.
Electrical Standards	45	0	0
Seismological Observations...	75	0	0
Wave-length Tables...........	4	14	0
Isomorphous Sulphonic Derivatives of Benzene	35	0	0
Life-zones in British Carboniferous Rocks	20	0	0
Underground Water of North-west Yorkshire	50	0	0
Exploration of Irish Caves...	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium.....................	75	0	0
Migration of Birds	10	0	0
Terrestrial Surface Waves ...	5	0	0
Changes of Land-level in the Phlegræan Fields............	50	0	0
Legislation regulating Women's Labour..................	15	0	0
Small Screw Gauge	45	0	0
Resistance of Road Vehicles to Traction.....................	75	0	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	30	0	0
Anthropological Teaching ...	5	0	0
Exploration in Crete	145	0	0
Physiological Effects of Peptone..............................	30	0	0
Chemistry of Bone Marrow...	5	15	11
Suprarenal Capsules in the Rabbit...........................	5	0	0
Fertilisation in Phæophyceæ	15	0	0
Morphology, Ecology, and Taxonomy of Podostemaceæ...........................	20	0	0
Corresponding Societies Committee..........................	15	0	0
	£920	9	11

1902.

	£	s.	d.
Electrical Standards............	40	0	0
Seismological Observations...	35	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	80	0	0
Relation between Absorption Spectra and Organic Substances	20	0	0
Wave-length Tables	5	0	0
Life-zones in British Carboniferous Rocks	10	0	0
Exploration of Irish Caves ...	45	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Migration of Birds	15	0	0
Structure of Coral Reefs of Indian Ocean..................	50	0	0

	£	s.	d.
Compound Ascidians of the Clyde Area	25	0	0
Terrestrial Surface Waves	15	0	0
Legislation regulating Women's Labour	30	0	0
Small Screw Gauge	20	0	0
Resistance of Road Vehicles to Traction	50	0	0
Ethnological Survey of Canada	15	0	0
Age of Stone Circles	30	0	0
Exploration in Crete	100	0	0
Anthropometric Investigation of Native Egyptian Soldiers	15	0	0
Excavations on the Roman Site at Gelligaer	5	0	0
Changes in Hæmoglobin	15	0	0
Work of Mammalian Heart under Influence of Drugs	20	0	0
Investigation of the Cyanophyceæ	10	0	0
Reciprocal Influence of Universities and Schools	5	0	0
Conditions of Health essential to carrying on Work in Schools	2	0	0
Corresponding Societies Committee	15	0	0
	£947	0	0

1903.

	£	s.	d.
Electrical Standards	35	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	40	0	0
Study of Hydro-aromatic Substances	20	0	0
Erratic Blocks	10	0	0
Exploration of Irish Caves	40	0	0
Underground Waters of North-west Yorkshire	40	0	0
Life-zones in British Carboniferous Rocks	5	0	0
Geological Photographs	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Tidal Bore, Sea Waves, and Beaches	15	0	0
Scottish National Antarctic Expedition	50	0	0
Legislation affecting Women's Labour	25	0	0
Researches in Crete	100	0	0
Age of Stone Circles	3	13	2
Anthropometric Investigation	5	0	0
Anthropometry of the Todas and other Tribes of Southern India	50	0	0
The State of Solution of Proteids	20	0	0
Investigation of the Cyanophyceæ	25	0	0
Respiration of Plants	12	0	0
Conditions of Health essential for School Instruction	5	0	0
Corresponding Societies Committee	20	0	0
	£845	13	2

1904.

	£	s.	d.
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	50	0	0
Magnetic Observations at Falmouth	60	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	25	0	0
Erratic Blocks	10	0	0
Life-zones in British Carboniferous Rocks	35	0	0
Fauna and Flora of the Trias	10	0	0
Investigation of Fossiliferous Drifts	50	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	60	0	0
Development in the Frog	15	0	0
Researches on the Higher Crustacea	15	0	0
British and Foreign Statistics of International Trade	25	0	0
Resistance of Road Vehicles to Traction	90	0	0
Researches in Crete	100	0	0
Researches in Glastonbury Lake Village	25	0	0
Anthropometric Investigation of Egyptian Troops	8	10	0
Excavations on Roman Sites in Britain	25	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	40	0	0
Botanical Photographs	4	8	11
Respiration of Plants	15	0	0
Experimental Studies in Heredity	35	0	0
Corresponding Societies Committee	20	0	0
	£887	18	11

1905.

	£	s.	d.
Electrical Standards	40	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	40	0	0
Magnetic Observations at Falmouth	50	0	0
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism	20	0	0
Aromatic Nitramines	25	0	0
Fauna and Flora of the British Trias	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	75	0	0
Development of the Frog	10	0	0
Investigations in the Indian Ocean	150	0	0
Trade Statistics	4	4	8
Researches in Crete	75	0	0
Anthropometric Investigations of Egyptian Troops	10	0	0
Excavations on Roman Sites in Britain	10	0	0
Anthropometric Investigations	10	0	0
Age of Stone Circles	30	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	30	0	0
Ductless Glands	40	0	0
Botanical Photographs	3	17	6
Physiology of Heredity	35	0	0
Structure of Fossil Plants	50	0	0
Corresponding Societies Committee	20	0	0
	£928	2	2

1906.

	£	s.	d.
Electrical Standards	25	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	50	0	0
Magnetic Survey of South Africa	99	12	6
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Aromatic Nitramines	10	0	0
Fauna and Flora of the British Trias	7	8	11
Crystalline Rocks of Anglesey	30	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Frog	10	0	0
Higher Crustacea	15	0	0
Freshwater Fishes of South Africa	50	0	0
Rainfall and Lake and River Discharge	10	0	0
Excavations in Crete	100	0	0
Lake Village at Glastonbury	40	0	0
Excavations on Roman Sites in Britain	30	0	0
Anthropometric Investigations in the British Isles	30	0	0
State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	20	0	0
Effect of Climate upon Health and Disease	20	0	0
Research on South African Cycads	14	19	4
Peat Moss Deposits	25	0	0
Studies suitable for Elementary Schools	5	0	0
Corresponding Societies Committee	25	0	0
	£882	0	9

1907.

	£	s.	d.
Electrical Standards	50	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	40	0	0
Magnetic Survey of South Africa	25	7	6
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	30	0	0
Life Zones in British Carboniferous Rocks	10	0	0
Erratic Blocks	10	0	0
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone of South-West England	15	0	0
Correlation and Age of South African Strata, &c.	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Sexual Cells	1	11	8
Oscillations of the Land Level in the Mediterranean Basin	50	0	0
Gold Coinage in Circulation in the United Kingdom	8	19	7
Anthropometric Investigations in the British Isles	10	0	0
Metabolism of Individual Tissues	45	0	0
The Ductless Glands	25	0	0
Effect of Climate upon Health and Disease	55	0	0

	£	s.	d.
Physiology of Heredity	30	0	0
Research on South African Cycads	35	0	0
Botanical Photographs	5	0	0
Structure of Fossil Plants	5	0	0
Marsh Vegetation	15	0	0
Corresponding Societies Committee	16	14	1
	£757	12	10

1908.

	£	s.	d.
Seismological Observations	40	0	0
Further Tabulation of Bessel Functions	15	0	0
Investigation of Upper Atmosphere by means of Kites	25	0	0
Meteorological Observations on Ben Nevis	25	0	0
Geodetic Arc in Africa	200	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	40	0	0
Transformation of Aromatic Nitramines	30	0	0
Erratic Blocks	17	16	6
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
Pre-Devonian Rocks	10	0	0
Exact Significance of Local Terms	5	0	0
Composition of Charnwood Rocks	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Hereditary Experiments	10	0	0
Fauna of Lakes of Central Tasmania	40	0	0
Investigations in the Indian Ocean	50	0	0
Exploration in Spitsbergen	30	0	0
Gold Coinage in Circulation in the United Kingdom	3	7	6
Electrical Standards	50	0	0
Glastonbury Lake Village	30	0	0
Excavations on Roman Sites in Britain	15	0	0
Age of Stone Circles	50	0	0
Anthropological Notes and Queries	40	0	0
Metabolism of Individual Tissues	40	0	0
The Ductless Glands	13	14	8
Effect of Climate upon Health and Disease	35	0	0
Body Metabolism in Cancer	30	0	0
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
Marsh Vegetation	15	0	0
Succession of Plant Remains	18	0	0
Corresponding Societies Committee	25	0	0
	£1157	18	8

1909.

	£	s.	d.
Seismological Observations	60	0	0
Investigation of the Upper Atmosphere by means of Kites	10	0	0
Magnetic Observations at Falmouth	50	0	0
Establishing a Solar Observatory in Australia	50	0	0
Wave-length Tables of Spectra	9	16	0
Study of Hydro-aromatic Substances	15	0	0
Dynamic Isomerism	35	0	0
Transformation of Aromatic Nitramines	10	0	0
Electroanalysis	30	0	0
Fauna and Flora of British Trias	8	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	8	0	0
Palæozoic Rocks of Wales and the West of England	9	0	0
Igneous and Associated Sedimentary Rocks of Glensaul	11	13	9
Investigations at Biskra	50	0	0
Table at the Zoological Station at Naples	100	0	0
Heredity Experiments	10	0	0
Feeding Habits of British Birds	5	0	0
Index Animalium	75	0	0
Investigations in the Indian Ocean	35	0	0
Gaseous Explosions	75	0	0
Excavations on Roman Sites in Britain	5	0	0
Age of Stone Circles	30	0	0
Researches in Crete	70	0	0
The Ductless Glands	35	0	0
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
Reflex Muscular Rhythm	10	0	0
Anæsthetics	25	0	0
Mental and Muscular Fatigue	27	0	0
Structure of Fossil Plants	5	0	0
Botanical Photographs	10	0	0
Experimental Study of Heredity	30	0	0
Symbiosis between Turbellarian Worms and Algæ	10	0	0
Survey of Clare Island	65	0	0
Curricula of Secondary Schools	5	0	0
Corresponding Societies Committee	21	0	0
	£1014	9	9

REPORT OF THE COUNCIL, 1908-1909.

I. Dr. T. G. Bonney, F.R.S., has been unanimously nominated by the Council to fill the office of President of the Association for 1910 (Sheffield Meeting).

Mr. Francis Darwin, F.R.S., *President*, represented the Association at the Commemoration by the University of Cambridge of the Centenary of the Birth of Charles Darwin.

Dr. Augustus D. Waller, M.D., F.R.S., represented the Association at the Celebration of the 350th Anniversary of the foundation of the University of Geneva.

Sir J. Crichton Browne, M.D., LL.D., F.R.S., represented the Association at the Public Health Congress at Leeds.

II. The Council adopted a Resolution expressing the sympathy of the Association, through the General Secretaries, with the widow of the late Mr. J. Lomas, who was Recorder of Section C at the time of his death.

III. The following Nominations are made by the Council:—

Conference of Delegates.—Professor A. C. Haddon (*Chairman*), Mr. F. W. Rudler, I.S.O. (*Vice-Chairman*), Mr. W. P. D. Stebbing (*Secretary*).

Corresponding Societies Committee.—Mr. W. Whitaker (*Chairman*), Mr. W. P. D. Stebbing (*Secretary*), Rev. J. O. Bevan, Sir Edward Brabrook, Dr. J. G. Garson, Dr. E. H. Griffiths, Mr. T. V. Holmes, Mr. J. Hopkinson, Mr. A. L. Lewis, Professor R. Meldola, Dr. H. R. Mill, Mr. F. W. Rudler, Rev. T. R. R. Stebbing.

IV. A preliminary Report has been received from the Corresponding Societies Committee.

The Report contained the following paragraph:—

'The Committee desire to bring before the Council the unofficial position of the Chairman of the Conference of Delegates. They suggest that he should be *ex officio* a member of the Committee of Recommendations, and therefore in a similar position to the Presidents of Sections.'

The Council resolved to promulgate an amendment of the Rules, giving effect to the above suggestion, and in the meantime to invite the Chairman to be present at the meeting of the Committee of Recommendations.

V. A Resolution, referred to the Council by the General Committee at Dublin, has been received

From Sections A and E jointly:—

'That the Council should approach the Board of Agriculture with a view of ascertaining whether it is not possible for the Director-General of the Ordnance Survey of Great Britain and Ireland to undertake the remeasurement of the two principal arcs (meridional and longitudinal) as part of the current work of his department.'

Major C. F. Close submitted for the approval of the Council a draft letter addressed to the Secretary of the Board of Agriculture, to be signed by the President. This letter, with emendations, was approved, and ordered to be transmitted. It read as follows:—

British Association for the Advancement of Science,
Burlington House, London, W.
November 14th, 1908.

Sir Thomas Henry Elliott, K.C.B.,
Secretary of the Board of Agriculture and Fisheries,
4, *Whitehall Place, S.W.*

Sir,—I desire, on behalf of the Council of the British Association for the Advancement of Science, to represent to you, for the information of the President of the Board of Agriculture and Fisheries, that the Council have been requested by the Association to approach Lord Carrington, with a view to ascertaining whether it may not be possible for the Director-General of the Ordnance Survey to undertake the remeasurement of the two principal British arcs, meridional and longitudinal, as part of the current work of the Ordnance Survey.

The reasons which induce the Council to suggest the remeasurement are these:—

The principal triangulation of the United Kingdom, which is an excellent piece of work, considering that its mean date is about 1835, is, as compared with modern triangulations, below the standard now required for use in determining the Figure of the Earth. Making allowance for the fact that the triangulation is in the form of a net-work and not of a chain, it is thought that the errors in length and position are about twice as large as those of modern chains. It is not, however, easy to predict the magnitude of the errors of the British triangulation as compared with those of modern work; and the Council would suggest, for Lord Carrington's consideration, that it would be well, before definitely assuming that a remeasurement is desirable, to cause a section of the older portion of the triangulation, forming part of the meridional arc between the Shetland Islands and the Straits of Dover, to be remeasured with modern instruments.

The Council would further suggest that the experimental measurement should be undertaken by the existing staff of the Ordnance Survey, as opportunity offers; and, if Lord Carrington approves of the suggestion, the Council may be in a position to offer his Lordship the loan of a modern theodolite suitable for use in refined geodetic operations.

The Council desire to point out that their motive in venturing to put forward these suggestions is solely the scientific value of the remeasurement. They are aware that, for all practical map-making purposes, the existing triangulation is of quite sufficient accuracy; whilst they realise the high character of the work of the old observers and the importance of Colonel Clarke's discussion of that work.

I am, Sir,
Yours faithfully,
(*Signed*) Francis Darwin,
President of the British Association.

The Board of Agriculture having approved of Colonel S. C. Grant, of the Ordnance Survey Office, conferring with representatives of the Association and of the Royal Society on this matter, Sir David Gill and Major E. H. Hills were nominated to represent the Association.

VI. A Resolution, referred to the Council by the General Committee at Dublin, has been received

From Section A:—

'That the Committee of *Section A* has received with interest information respecting the Meteorological and Astronomical Observatory at Bulawayo, and desires the Council to inform the Chartered Company of the importance, from the scientific point of view, attached to the continuance of the observations, and to express the hope that the Chartered Company will see their way to continue the financial support to the Observatory.'

The Assistant Secretary was instructed to forward the Resolution, with the approval of the Council, to the Board of Directors of the British South Africa Company.

VII. A Resolution, referred to the Council by the General Committee at Dublin, has been received

From Section D:—

'That the Council be requested to communicate a Resolution of *Section D* relating to Zoological Nomenclature to the International Commission on Nomenclature and to certain British scientific societies.'

On the motion of Professor Herdman, a Committee, consisting of Dr. S. F. Harmer, Mr. G. A. Boulenger, Professor E. B. Poulton, Dr. W. E. Hoyle, Rev. T. R. R. Stebbing, Dr. A. Smith Woodward, Mr. E. T. Newton, and the General Officers, was appointed to consider this Resolution and to report to the Council. The Committee reported as follows:—

'The Committee appointed to report on the Resolutions submitted by Section D to the Council wish to endorse the action of Section D.

'They recommend that Resolutions (i), (ii), and (iii) be sent to the International Commission on Scientific Nomenclature and to the chief British zoological societies, accompanied by a reprint of the manifesto published in "Nature," and referred to in Resolution (i).

'The Committee wish to inform the Council that this recommendation was supported by Dr. S. F. Harmer, Dr. W. E. Hoyle, Mr. E. T. Newton, and Dr. A. Smith Woodward; and that Mr. T. R. R. Stebbing dissented from it.'

It was resolved:

'That the Council of the British Association desire to draw the attention of the International Commission on Zoological Nomenclature and the chief British zoological societies to

the Resolutions adopted by the Committee of Section D (Zoology) at the Dublin Meeting of the British Association in September 1908.'

VIII. A Resolution, referred to the Council by the General Committee at Dublin, has been received

From Section H, supported by Section E:—

'That the Council of the British Association be requested to lend their support to the project for an Imperial Bureau of Anthropology set on foot by the Royal Anthropological Institute. A memorial in favour of the scheme has already been numerously signed by distinguished Indian and Colonial administrators, heads and parliamentary representatives of universities, principals of university colleges, anthropologists, directors of steamship companies, leading manufacturers, and heads of other mercantile enterprises; and it will be presented to the Chancellor of the Exchequer in the coming session of Parliament by a deputation composed of some of the chief signatories.'

The Resolution was adopted by the Council; and it was agreed that the signature of the President should be affixed to the Memorial.

IX. A Resolution, referred to the Council by the General Committee at Dublin, has been received

From Section L:—

(i) 'That, in the opinion of this Committee, it is desirable that the Committee of Recommendations should meet on Tuesday afternoon with a view to the consideration of the Papers recommended by Sectional Committees to be printed *in extenso* in the Annual Report.

(ii) 'That 1,000 reprints of the Report presented this year upon Practical Studies in Elementary Schools, with the introduction prepared by Sir Philip Magnus, be supplied to the Secretary of the Committee for distribution.

(iii) 'That 500 reprints of the Report presented this year upon the Sequence of Science Studies in Secondary Schools be supplied to the Secretary of the Sub-Committee for distribution.'

The Council rejected the proposal made in the first paragraph, and were informed that the General Committee at Dublin had already given its assent to the requests made under paragraphs (ii) and (iii).

X. A Resolution, referred to the Council by the General Committee at Dublin, has been received

From the Conference of Delegates:—

'That Conference desires to represent to the Committee of Recommendations that whenever a Committee of the British Association enters upon a local investigation, notice should be given to any local scientific or archæological society, so

as to enable that Society to offer any co-operation that may be desirable.'

The Council approved this proposal and of Sir Edward Brabrook's suggestion that, if necessary, a copy of the Resolution should be sent to the Chairman of each Research Committee.

XI. The following Resolution adopted by the *Corresponding Societies Committee* at a Special Meeting has been submitted by Sir Edward Brabrook:—

'That the Corresponding Societies Committee should, as a matter of urgency, ask for power from the Council of the British Association to extend its work for this purpose—*i.e.*, to endeavour to obtain financial assistance in the work of printing and publishing the results of original investigations —to all the purely scientific societies in the Kingdom publishing original investigations.'

Sir Edward explained that the object of the proposed inquiry was to ascertain whether the publishing activity of the societies is being crippled (and, if so, to what extent) for want of sufficient means to enable them to print and publish all the original work carried out by their members or fellows.

The Council authorised the Corresponding Societies Committee to undertake the inquiry and to extend its scope to all societies in the United Kingdom.

XII. Recommendations, received by the General Committee at Dublin and referred to the Council, were dealt with as under:—

(i) It was agreed that the following Committees be authorised to receive contributions from sources other than the Association —namely, the Committee 'To conduct Explorations with the object of ascertaining the Age of Stone Circles' (*Section H*), and the Committee on 'The Effect of Climate upon Health and Disease' (*Section I*).

(ii) It was agreed that *Section G* be authorised to publish the Report of their Committee on 'Gaseous Explosions' in such public journals as may seem desirable.

(iii) It was agreed that, in accordance with the recommendation of the Committee of *Section H*, the Report of the Anthropometric Committee be printed in full in the Dublin Report, with the addition of the illustrations from the blocks in the possession of the Association.

(iv) Following a request from the Committee of *Section A*, recommending that the Reports of the Electrical Standards Committee from 1862 onwards be reprinted and published as a Memorial to the late Lord Kelvin, it was resolved that:

'The Council will recommend, at the Winnipeg Meeting, that the Reports of the Electrical Standards Committee be republished in book form, by the Cambridge University Press as a Memorial of the late Lord Kelvin.'

XIII. On the proposal made at the meeting of the General Committee, September 9, 1908, 'That for future Annual Meetings the abstracts of Sectional Transactions should be printed and bound in pamphlet form, Section by Section, and published collectively within two months after the British Association Meeting, at a moderate price,' the TREASURER reported that on investigation it appeared improbable that the cost of carrying out the proposal would be covered by the receipts, that there would be difficulty in making up complete sets of the abstracts within two months of the Meeting, and that it was not desirable to make any such experiment at a Colonial Meeting. He proposed that the matter should stand over until next year, and that in 1910 unbound sets of the abstracts printed before the Meeting should be made up for each Section and put on sale on and after the last day of the Annual Meeting.

The Report and proposals were adopted.

XIV. The Council have authorised Section K (Botany) to form a SUB-SECTION FOR AGRICULTURE for the Winnipeg Meeting, with a Chairman, Vice-Chairmen, and Secretariat to deal with its transactions.

XV. The Council have received reports from the General Treasurer during the past year. His ACCOUNTS from July 1, 1908, to June 30, 1909, have been audited and are presented to the General Committee.

XVI. In accordance with the Regulations, the retiring Members of the COUNCIL are:—

(i) *Retiring by seniority:* Professor G. C. Bourne, Charles Hawksley, Professor W. W. Watts.
(ii) *Retiring by least attendance:* Professor A. R. Forsyth (resigned during the year), Professor J. G. McKendrick.

The Council nominated the following new members:—Dr. H. E. Armstrong, Dr. J. J. H. Teall, and Sir John Wolfe-Barry, K.C.B., leaving two vacancies to be filled up by the General Committee without nomination by the Council.

XVII. The General Officers have been nominated by the Council for reappointment.

XVIII. A Committee of the Council, consisting of the President, the President-Elect, the General Officers, Sir Archibald Geikie, Sir Edward Brabrook, Mr. Vernon Harcourt, and Dr. Carey Foster, was appointed to consider a letter of resignation from Mr. A. Silva White, Assistant Secretary, and, if necessary, to select and recommend a successor to this office, with the result that Mr. White's resignation was accepted, and that Mr. O. J. R. Howarth was appointed to the Assistant Secretaryship from February 8, 1909.

XIX. The following have been admitted as Members of the GENERAL COMMITTEE:—

Arnold-Bemrose, H. H., Sc.D.
Beadnell, H. J. Llewellyn.
Bigg-Wither, Col. A. C., F.R.A.S.
Clarke, Miss Lilian J., F.L.S.
Dixon, Ernest.
Hastings, Geoffrey.
Heller, W. M., B.Sc.
Holt, Alfred, jun., B.A., M.Sc.
Marchant, Prof. E. W., D.Sc.
Thomas, Miss E. N.
Thorpe, Jocelyn F., Ph.D., F.R.S
Woolacott, David, D.Sc.

Dr. THE GENERAL TREASURER'S ACCOUNT,

1908–1909. RECEIPTS.

	£	s.	d.	£	s.	d.
Balance brought forward				518	17	5
Life Compositions (including Transfers)				439	0	0
New Annual Members' Subscriptions				266	0	0
Annual Subscriptions				701	0	0
Sale of Associates' Tickets				1,155	0	0
Sale of Ladies' Tickets				221	0	0
Sale of Publications				221	19	11
Dividend on Consols				154	8	4
Dividend on India 3 per Cents.				102	12	0
Great Indian Peninsula Railway 'B' Annuity				49	11	0
Interest on Deposit				15	10	11
Unexpended Balances returned:—						
Bessel Functions	13	7	8			
Fauna and Flora of British Trias	8	7	6			
Structure of Fossil Plants	1	9	0			
Age of Stone Circles	1	6	1			
Corresponding Societies Committee	1	10	5			
Anthropometric Investigations in the British Isles		2	0			
Pre-Devonian Rocks		13	0			
Marsh Vegetation		12	2			
Electrical Standards	1	0	4			
				28	8	2
				£3,873	7	9

Investments.

	£	s.	d.
$2\frac{1}{2}$ per Cent. Consolidated Stock	6,501	10	5
India 3 per Cent. Stock	3,600	0	0
£73 Great Indian Peninsula Railway 'B' Annuity (cost)	1,493	6	6
	11,594	16	11
Sir Frederick Bramwell's Gift:— $2\frac{1}{2}$ per Cent. Self-cumulating Consolidated Stock	67	4	1
	£11,662	1	0

JOHN PERRY, *Treasurer.*

from July 1, 1908, to June 30, 1909. *Cr.*

1908–1909. PAYMENTS.

	£ s. d.	£ s. d.
Rent and Office Expenses		138 3 5
Salaries, &c.		754 5 8
Printing, Binding, &c.		1,152 2 6
Expenses of Dublin Meeting		272 5 8
Payment of Grants made at Dublin:		
Seismological Observations	60 0 0	
Investigation of the Upper Atmosphere by means of Kites	10 0 0	
Magnetic Observations at Falmouth	50 0 0	
Establishing a Solar Observatory in Australia	50 0 0	
Wave-length Tables of Spectra	9 16 0	
Study of Hydro-aromatic Substances	15 0 0	
Dynamic Isomerism	35 0 0	
Transformation of Aromatic Nitramines	10 0 0	
Electroanalysis	30 0 0	
Fauna and Flora of British Trias	8 0 0	
Faunal Succession in the Carboniferous Limestone in the British Isles	8 0 0	
Palæozoic Rocks of Wales and the West of England	9 0 0	
Igneous and Associated Sedimentary Rocks of Glensaul	11 13 9	
Investigations at Biskra	50 0 0	
Table at the Zoological Station at Naples	100 0 0	
Heredity Experiments	10 0 0	
Feeding Habits of British Birds	5 0 0	
Index Animalium	75 0 0	
Investigations in the Indian Ocean	35 0 0	
Gaseous Explosions	75 0 0	
Excavations on Roman Sites in Britain	5 0 0	
Age of Stone Circles	30 0 0	
Researches in Crete	70 0 0	
The Ductless Glands	35 0 0	
Electrical Phenomena and Metabolism of *Arum Spadices*	10 0 0	
Reflex Muscular Rhythm	10 0 0	
Anæsthetics	25 0 0	
Mental and Muscular Fatigue	27 0 0	
Structure of Fossil Plants	5 0 0	
Botanical Photographs	10 0 0	
Experimental Study of Heredity	30 0 0	
Symbiosis between Turbellarian Worms and Algæ	10 0 0	
Survey of Clare Island	65 0 0	
Curricula of Secondary Schools	5 0 0	
Corresponding Societies Committee	21 0 0	
		1,014 9 9
		£3,331 7 0
Balance at Bank of England (Western Branch)	635 14 6	
Less Cheques not presented	93 13 9	
		542 0 9
		£3,873 7 9

I have examined the above Account with the Books and Vouchers of the Association, and certify the same to be correct. I have also verified the Balance at the Bankers', and have ascertained that the Investments are registered in the names of the Trustees. In addition to the sums accounted for above, there had been received £290 at June 30, 1909, on account of the Winnipeg Meeting, which will be brought into next year's account.

Approved—
EDWARD BRABROOK, } *Auditors.*
HERBERT MCLEOD, }

W. B. KEEN, *Chartered Accountant.*
July 16, 1909.

GENERAL MEETINGS AT WINNIPEG.

On Wednesday, August 25, at 8.30 P.M., in the Walker Theatre, a letter from the retiring President, Dr. Francis Darwin, F.R.S., having been read, Professor Sir J. J. Thomson, F.R.S., took the Chair and delivered an Address, for which see p. 3.

On Thursday, August 26, at 8.30 P.M., in the Walker Theatre, Dr. A. E. H. Tutton delivered a Discourse on 'The Seven Styles of Crystal Architecture.'

On Friday, August 27, at 9 P.M., his Honour the Lieutenant-Governor held a Reception at Government House.

On Monday, August 30, at 9 P.M., a Conversazione was held at the Royal Alexandra Hotel.

On Tuesday, August 31, at 8.30 P.M., in the Walker Theatre, Professor W. A. Herdman, F.R.S., delivered a Discourse on 'Our Food from the Waters.'

On Wednesday, September 1, at 3 P.M., the concluding General Meeting was held in the Legislative Chamber, when the following Resolutions were adopted :—

1. That a cordial vote of thanks be given to the Governments of the Dominion of Canada and the Province of Manitoba and to the City of Winnipeg for the generous support which has enabled the Association to hold its meeting in Winnipeg.

2. That a cordial vote of thanks be given to the Mayor, the Controllers, and the City Council of Winnipeg for the reception which they have accorded to the British Association and for the facilities placed at the disposal of the officers of the Association.

3. That a cordial vote of thanks be given (1) to the Local Executive Officers and Committees for the admirable arrangements made for the meetings; (2) to the public institutions which have granted the use of their buildings for sectional proceedings; and (3) to the proprietors and managers of works thrown open to the inspection of the members.

4. That the grateful thanks of the Association be given to the citizens of Winnipeg for the generous hospitality shown to its members on the occasion of this meeting.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE WINNIPEG MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Prof. E. Rutherford, F.R.S. *Vice-Presidents.*—Prof. E. W. Brown, F.R.S.; Prof. E. W. Hobson, F.R.S.; Prof. Sir Joseph Larmor, Sec.R.S.; Prof. J. C. McLennan; Dr. W. N. Shaw, F.R.S. *Secretaries.*—Prof. A. W. Porter, B.Sc. (*Recorder*); Prof. F. Allen, Ph.D.; Prof. J. C. Fields; E. Gold, M.A.; F. Horton; Dr. A. A. Rambaut, F.R.S.

SECTION B.—CHEMISTRY.

President.—Prof. H. E. Armstrong, F.R.S. *Vice-Presidents.*—Prof. F. S. Kipping, F.R.S.; Prof. W. A. Noyes; Prof. M. A. Parker, B.Sc.; Prof. W. P. Wynne, F.R.S. *Secretaries.*—Dr. E. F. Armstrong (*Recorder*); Dr. T. M. Lowry; Dr. F. M. Perkin; J. W. Shipley, B.A.

SECTION C.—GEOLOGY.

President.—Dr. A. Smith Woodward, F.R.S. *Vice-Presidents.*—Prof. F. D. Adams, F.R.S.; Prof. A. P. Coleman, Ph.D.; Prof. J. W. Gregory, F.R.S.; Prof. W. C. Miller; A. Strahan, F.R.S. *Secretaries.*—W. Lower Carter, M.A. (*Recorder*); A. R. Dwerryhouse, D.Sc.; R. T. Hodgson, M.A.; Prof. S. H. Reynolds, M.A.

SECTION D.—ZOOLOGY.

President.—Dr. A. E. Shipley, F.R.S. *Vice-Presidents.*—J. Stanley Gardiner, F.R.S.; E. S. Goodrich, F.R.S.; Prof. A. B. Macallum, F.R.S.; Prof. E. E. Prince. *Secretaries.*—H. W. Marett Tims, M.A., M.D. (*Recorder*); C. A. Baragar; C. L. Boulenger; Dr. J. Pearson.

SECTION E.—GEOGRAPHY.

President.—Colonel Sir Duncan Johnston, K.C.M.G., C.B., R.E. *Vice-Presidents.*—Dr. Tempest Anderson; Colonel A. C. Bigg-Wither. *Secretaries.*—G. G. Chisholm, B.Sc. (*Recorder*); J. McFarlane, M.A.; A. McIntyre, B.A.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—Prof. S. J. Chapman, M.A., M.Com. *Vice-Presidents.*—Dr. James Bonar; Prof. A. L. Bowley, M.A.; Major P. G. Craigie, C.B. *Secretaries.*—Dr. W. R. Scott, M.A. (*Recorder*); Prof. A. B. Clark, M.A.; W. A. Manahan, Ph.D.

SECTION G.—ENGINEERING.

President.—Sir W. H. White, K.C.B., F.R.S. *Vice-Presidents.*—Lieut.-Col. W. P. Anderson; Colonel H. N. Ruttan; J. E. Schwitzer; Colonel Sir C. M. Watson, K.C.M.G., C.B., R.E. *Secretaries.*—W. A. Price (*Recorder*); E. E. Brydone-Jack, B.A.; Prof. E. G. Coker, D.Sc.; Prof. E. W. Marchant, D.Sc.

SECTION H.—ANTHROPOLOGY.

President.—Prof. J. L. Myres, M.A., F.S.A. *Vice-Presidents.*—Dr. F. Boas; Rev. Dr. G. Bryce, P.R.S.C.; E. Sidney Hartland, F.S.A.; Prof. G. G. MacCurdy. *Secretaries.*—H. S. Kingsford, M.A. (*Recorder*); Prof. C. J. Patten, M.D.; Dr. F. C. Shrubsall.

SECTION I.—PHYSIOLOGY.

President.—Prof. E. H. Starling, F.R.S. *Vice-Presidents.*—Prof. A. R. Cushny, F.R.S.; W. B. Hardy, F.R.S.; Prof. A. B. Macallum, F.R.S.; Dr. A. D. Waller, F.R.S. *Secretaries.*—N. H. Alcock, M.D. (*Recorder*); Prof. P. T. Herring, M.D.; W. Webster, M.D.

SECTION K.—BOTANY.

President.—Lieut.-Col. D. Prain, C.I.E., F.R.S. *Vice-Presidents.*—Prof. D. H. Campbell; Harold W. T. Wager, F.R.S. *Secretaries.*—Prof. R. H. Yapp, M.A. (*Recorder*); Prof. A. H. Reginald Buller, D.Sc.; Prof. D. T. Gwynne-Vaughan, M.A.

SUB-SECTION.—AGRICULTURE.

Chairman.—Major P. G. Craigie, C.B. *Vice-Chairman.*—Prof. W. Somerville, D.Sc. *Secretaries.*—Dr. E. J. Russell (*Recorder*); W. J. Black, B.S.A.; Prof. James Wilson, M.A.

SECTION L.—EDUCATIONAL SCIENCE.

President.—Rev. H. B. Gray, D.D. *Vice-Presidents.*—W. M. Heller, B.Sc.; Dr. C. W. Kimmins; Dr. Hugo Munsterberg; Dr. J. W. Robertson, C.M.G. *Secretaries.*—J. L. Holland, B.A. (*Recorder*); W. D. Eggar, M.A.; R. Fletcher, M.A.; Hugh Richardson, M.A.

COMMITTEE OF RECOMMENDATIONS.

The President and Vice-Presidents of the Association; the General Secretaries; the General Treasurer; the Trustees; the Presidents of the Association in former years; Prof. E. Rutherford; Prof. J. H. Poynting; Prof. H. E. Armstrong; Dr. E. F. Armstrong; Dr. A. Smith Woodward; W. Lower Carter; Dr. A. E. Shipley; Dr. H. W. Marett Tims; Colonel A. C. Bigg-Wither; G. G. Chisholm; Prof. S. J. Chapman; Prof. A. B. Clark; Sir W. H. White; W. A. Price; Prof. J. L. Myres; E. Sidney Hartland; Prof. E. H. Starling; Prof. A. R. Cushny; Colonel D. Prain; Major P. G. Craigie; Rev. Dr. H. B. Gray; and J. L. Holland.

Research Committees, etc., appointed by the General Committee at the Winnipeg Meeting: August 1909.

1. *Receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee	Grants
	RECOMMENDED BY COUNCIL.	
		£ s. d.
To carry out a further portion of the Geodetic Arc of Meridian North of Lake Tanganyika.	*Chairman.*—Sir George Darwin. *Secretary.*—Sir David Gill. Colonel Close and Sir Geo. Goldie.	100 0 0
To republish Reports of the Electrical Standards Committee in book form, as a memorial of the late Lord Kelvin.	Dr. R. T. Glazebrook. (*No Committee appointed.*)	100 0 0
	SECTION A.—MATHEMATICS AND PHYSICS.	
Seismological Observations.	*Chairman.*—Professor H. H. Turner. *Secretary.*—Dr. J. Milne. Dr. T. G. Bonney, Mr. C. V. Boys, Mr. Horace Darwin, Major L. Darwin, Professor J. A. Ewing, Dr. R. T. Glazebrook, Mr. M. H. Gray, Professors J. W. Judd, C. G. Knott, and R. Meldola, Mr. R. D. Oldham, Professor J. Perry, Mr. W. E. Plummer, Professor J. H. Poynting, Mr. Clement Reid, and Mr. Nelson Richardson.	60 0 0
To co-operate with the Committee of the Falmouth Observatory in their Magnetic Observations.	*Chairman.*—Sir W. H. Preece. *Secretary.*—Dr. R. T. Glazebrook. Professor W. G. Adams, Captain Creak, Mr. W. L. Fox, Professor A. Schuster, Sir A. W. Rücker, and Dr. Charles Chree.	25 0 0
To aid the work of Establishing a Solar Observatory in Australia.	*Chairman.*—Sir David Gill. *Secretary.*—Dr. W. G. Duffield. Dr. W. J. S. Lockyer, Mr. F. McClean, and Professors A. Schuster and H. H. Turner.	50 0 0
Investigation of the Upper Atmosphere.	*Chairman.*—Dr. W. N. Shaw. *Secretary.*—Mr. E. Gold. Mr. D. Archibald, Mr. C. Vernon Boys, Mr. C. J. P. Cave, Mr. W. H. Dines, Dr. R. T. Glazebrook, Professor J. E. Petavel, Dr. A. Schuster, Dr. W. Watson, and Sir J. Larmor.	25 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
Section B.—CHEMISTRY.		£ s. d.
The Study of Hydro-aromatic Substances.	*Chairman.*—Dr. E. Divers. *Secretary.*—Professor A. W. Crossley. Professor W. H. Perkin, Dr. M. O. Forster, and Dr. Le Sueur.	25 0 0
Dynamic Isomerism.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Dr. T. M. Lowry. Professor Sydney Young, Dr. Desch, Dr. J. J. Dobbie, Dr. A. Lapworth, and Dr. M. O. Forster.	35 0 0
The Transformation of Aromatic Nitroamines and allied substances, and its relation to Substitution in Benzene Derivatives.	*Chairman.*—Professor F. S. Kipping. *Secretary.*—Professor K. J. P. Orton. Dr. S. Ruhemann, Dr. A. Lapworth, and Dr. J. T. Hewitt.	15 0 0
Electroanalysis.	*Chairman.*—Professor F. S. Kipping. *Secretary.*—Dr. F. M. Perkin. Dr. G. T. Beilby, Dr. T. M. Lowry, Professor W. J. Pope, and Mr. H. J. S. Sand.	10 0 0
Section C.—GEOLOGY.		
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.	*Chairman.*—Mr. R. H. Tiddeman. *Secretary.*—Dr. A. R. Dwerryhouse. Dr. T. G. Bonney, Mr. F. M. Burton, Mr. F. W. Harmer, Rev. S. N. Harrison, Dr. J. Horne, Mr. W. Lower Carter, Professor W. J. Sollas, and Messrs. J. W. Stather and W. T. Tucker.	10 0 0
To enable Mr. E. Greenly to complete his Researches on the Composition and Origin of the Crystalline Rocks of Anglesey.	*Chairman.*—Mr. A. Harker. *Secretary.*—Mr. E. Greenly. Dr. J. Horne, Dr. C. A. Matley, and Professor K. J. P. Orton.	1 0 0
To enable Dr. A. Vaughan to continue his Researches on the Faunal Succession in the Carboniferous Limestone in the British Isles.	*Chairman.*—Professor J. W. Gregory. *Secretary.*—Dr. A. Vaughan. Dr. Wheelton Hind and Professor W. W. Watts.	10 0 0
To excavate Critical Sections in the Palæozoic Rocks of Wales and the West of England.	*Chairman.*—Professor C. Lapworth. *Secretary.*—Mr. W. G. Fearnsides. Dr. J. E. Marr, Professor W. W. Watts, and Mr. G. J. Williams.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
To investigate the Microscopical and Chemical Composition of Charnwood Rocks.	*Chairman.* — Professor W. W. Watts. *Secretary.*—Dr. T. T. Groom. Dr. F. W. Bennett, Mr. C. Fox-Strangways, and Dr. Stracey.	2 0 0
The Investigation of Igneous and Associated Rocks of Glensaul and Lough Nafooey Areas, Co. Galway.	*Chairman.* — Professor W. W. Watts. *Secretary.*—Professor S. H. Reynolds. Messrs. H. B. Maufe and C. I. Gardiner.	15 0 0
To investigate and report on the Correlation and Age of South African Strata and on the question of a Uniform Stratigraphical Nomenclature.	*Chairman.*—Professor J. W. Gregory. *Secretary.*—Professor A. Young. Mr. W. Anderson, Professor R. Broom, Dr. G. S. Corstorphine, Mr. Walcot Gibson, Dr. F. H. Hatch, Sir T. H. Holland, Mr. H. Kynaston, Mr. F. P. Mennell, Dr. Molengraaff, Mr. A. J. C. Molyneux, Mr. A. W. Rogers, Mr. E. H. L. Schwarz, and Professor R. B. Young.	5 0 0
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor J. Geikie. *Secretary.* — Professor W. W. Watts. Dr. T. Anderson, Mr. G. Bingley, Dr. T. G. Bonney, Mr. H. Coates, Mr. C. V. Crook, Professor E. J. Garwood, Messrs. W. Gray, W. J. Harrison, R. Kidston, and A. S. Reid, Professor S. H. Reynolds, and Messrs. J. J. H. Teall, R. Welch, and H. B. Woodward.	10 0 0
To investigate the Fossil Flora and Fauna of the Midland Coalfields.	*Chairman.*—Dr. A. Strahan. *Secretary.*—Dr. F. W. Bennett. Dr. Wheelton Hind, Mr. B. Hobson, Mr. H. Bolton, and Dr. A. R. Dwerryhouse.	25 0 0
SECTION D.—ZOOLOGY.		
To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Professor S. J. Hickson. *Secretary.*—Rev. T. R. R. Stebbing. Sir E. Ray Lankester, Professor A. Sedgwick, Professor W. C. McIntosh, Dr. S. F. Harmer, Mr. G. P. Bidder, and Dr. W. B. Hardy.	75 0 0
Compilation of an Index Generum et Specierum Animalium.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Dr. F. A. Bather. Dr. P. L. Sclater, Rev. T. R. R. Stebbing, Dr. W. E. Hoyle, the Hon. Walter Rothschild, and Lord Walsingham.	75 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
To enable Mr. Laurie to conduct Experiments in Inheritance.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Mr. Douglas Laurie. Mr. R. C. Punnett and Dr. H. W. Marett Tims.	15 0 0
To investigate the Feeding Habits of British Birds by a study of the contents of the crops and gizzards of both adults and nestlings, and by the collation of observational evidence, with the object of obtaining precise knowledge as to the economic status of many of our commoner birds affecting rural science.	*Chairman.*—Dr. A. E. Shipley. *Secretary.*—Mr. H. S. Leigh. Messrs. J. N. Halbert, Robert Newstead, Clement Reid, A. G. L. Rogers, F. V. Theobald, Prof. F. E. Weiss, and Mr. C. Gordon Hewitt.	5 0 0
To investigate the Fauna of the Prairie Provinces of Canada.	*Chairman.*—Prof. Swale Vincent. *Secretary.*—Mr. G. E. Atkinson. Prof. McBride, Mr. J. C. Simpson, Rev. Dr. G. Bryce, and Dr. H. W. Marett Tims.	15 0 0
Section F.—ECONOMIC SCIENCE AND STATISTICS.		
The Amount of Gold Coinage in Circulation in the United Kingdom.	*Chairman.*—Sir R. H. Inglis Palgrave. *Secretary.*—Mr. H. Stanley Jevons. Professor Edgeworth and Messrs. A.L. Bowley and D.H. Macgregor.	6 0 0
The Amount and Distribution of Income (other than Wages) below the Income-tax exemption limit in the United Kingdom.	*Chairman.*—Professor E. Cannan. *Secretary.*—Professor A. L. Bowley. Mr. W. G. S. Adams, Dr. W. R. Scott, and Professors F. Y. Edgeworth and H. B. Lees Smith.	15 0 0
Section G.—ENGINEERING.		
The Investigation of Gaseous Explosions, with special reference to Temperature.	*Chairman.*—Sir W. H. Preece. *Secretaries.*—Mr. Dugald Clerk and Professor B. Hopkinson. Professors W. A. Bone, F. W. Burstall, H. L. Callendar, E. G. Coker, W. E. Dalby, and H. B. Dixon, Drs. R. T. Glazebrook, J. A. Harker, and H. S. Hele-Shaw, Colonel H. C. L. Holden, Mr. J. E. Petavel, Captain H. Riall Sankey, and Professors A. Smithells and W. Watson.	75 0 0
Section H.—ANTHROPOLOGY.		
To investigate the Lake Villages in the neighbourhood of Glastonbury in connection with a Committee of the Somerset Archæological and Natural History Society.	*Chairman.*—Dr. R. Munro. *Secretary.*—Professor W. Boyd Dawkins. Professor W. Ridgeway and Messrs. Arthur J. Evans, C. H. Read, H. Balfour, and A. Bulleid.	5 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
To co-operate with Local Committees in Excavations on Roman Sites in Britain.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Professor R. C. Bosanquet. Dr. T. Ashby and Professor W. Ridgeway.	5 0 0
To conduct Explorations with the object of ascertaining the Age of Stone Circles.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. H. Balfour. Lord Avebury, Professor W. Ridgeway, Dr. J. G. Garson, Dr. A. J. Evans, Dr. R. Munro, Professor Boyd Dawkins, and Mr. A. L. Lewis.	30 0 0
To prepare a New Edition of Notes and Queries in Anthropology.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Professor J. L. Myres. Mr. E. N. Fallaize, Dr. A. C. Haddon, Mr. T. A. Joyce, and Drs. C. S. Myers, W. H. R. Rivers, C. G. Seligmann, and F. C. Shrubsall.	40 0 0
To conduct Archæological and Ethnological Researches in Crete.	*Chairman.*—Mr. D. G. Hogarth. *Secretary.*—Professor J. L. Myres. Professor R. C. Bosanquet, Dr. W. L. H. Duckworth, Dr. A. J. Evans, Professor A. Macalister, Professor W. Ridgeway, and Dr. F. C. Shrubsall.	70 0 0
To excavate Neolithic Sites in Northern Greece.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Professor J. L. Myres. Mr. J. P. Droop and Mr. D. G. Hogarth.	5 0 0

SECTION I.—PHYSIOLOGY.

The Ductless Glands.	*Chairman.*—Professor Schäfer. *Secretary.*—Professor Swale Vincent. Professor A. B. Macallum, Dr. L. E. Shore, and Mrs. W. H. Thompson.	40 0 0
Body Metabolism in Cancer.	*Chairman.*—Professor C. S. Sherrington. *Secretary.*—Dr. S. M. Copeman.	20 0 0
To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Professor S. J. Hickson. *Secretary.*—Rev. T. R. R. Stebbing. Sir E. Ray Lankester, Professor A. Sedgwick, Professor W. C. McIntosh, Dr. S. F. Harmer, Mr. G. P. Bidder, and Dr. W. B. Hardy.	25 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
To acquire further knowledge, Clinical and Experimental, concerning Anæsthetics—especially Chloroform, Ether, and Alcohol—with Special Reference to Deaths by or during Anæsthesia, and their possible Diminution.	*Chairman.*—Dr. A. D. Waller. *Secretary.*—Dr. F. W. Hewitt. Dr. Blumfeld, Mr. J. A. Gardner, and Dr. G. A. Buckmaster.	25 0 0
Tissue Metabolism, for the Investigation of the Metabolism of Special Organs.	*Chairman.*—Professor E. H. Starling. *Secretary.*—Professor T. G. Brodie. Dr. J. S. Haldane.	25 0 0
Mental and Muscular Fatigue.	*Chairman.*—Professor C. S. Sherrington. *Secretary.*—Dr. W. MacDougall. Professor J. S. MacDonald and Mr. H. Sackville Lawson.	20 0 0
Electromotive Phenomena in Plants.	*Chairman.*—Dr. A. D. Waller. *Secretary.*—Mrs. Waller. Professors F. Gotch, J. B. Farmer and Veley, and Dr. F. O'B. Ellison.	10 0 0
The Dissociation of Oxy-Hæmoglobin at High Altitudes.	*Chairman.*—Professor E. H. Starling. *Secretary.*—Dr. J. Barcroft. Dr. W. B. Hardy.	15 0 0
Section K.—BOTANY.		
The Structure of Fossil Plants.	*Chairman.*—Dr. D. H. Scott. *Secretary.*—Professor F. W. Oliver. Mr. E. Newell Arber and Professors A. C. Seward and F. E. Weiss.	10 0 0
The Experimental Study of Heredity.	*Chairman.*—Mr. Francis Darwin *Secretary.*—Mr. A. G. Tansley. Professors Bateson and Keeble.	30 0 0
The Investigation of Symbiosis between Turbellarian Worms and Algæ.	*Chairman.*—Dr. F. F. Blackman. *Secretary.*—Professor F. E. Weiss. Professors Keeble and Nuttall.	5 0 0
A Botanical, Zoological, and Geological Survey of Clare Island.	*Chairman.*—Professor T. Johnson. *Secretary.*—Mr. R. Lloyd Praeger. Professor Grenville Cole, Dr. Scharff, and Mr. A. G. Tansley.	30 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
Section L.—EDUCATIONAL SCIENCE.		
		£ s. d.
To report upon the Course of Experimental, Observational, and Practical Studies most suitable for Elementary Schools.	*Chairman.*—Sir Philip Magnus. *Secretary.*—Mr. W. M. Heller. Sir W. de W. Abney, Mr. R. H. Adie, Professor H. E. Armstrong, Miss L. J. Clarke, Miss A. J. Cooper, Mr. George Fletcher, Professor R. A. Gregory, Principal Griffiths, Mr. A. D. Hall, Dr. A. J. Herbertson, Dr. C. W. Kimmins, Professor L. C. Miall, Professor J. Perry, Mrs. W. N. Shaw, Professor A. Smithells, Dr. Lloyd Snape, Sir H. R. Reichel, Mr. H. Richardson, and Professor W. W. Watts.	5 0 0
CORRESPONDING SOCIETIES.		
Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Mr. W. Whitaker. *Secretary.*—Mr. W. P. D. Stebbing. Rev. J. O. Bevan, Sir Edward Brabrook, Dr. J. G. Garson, Principal E. H. Griffiths, Mr. T. V. Holmes, Mr. J. Hopkinson, Mr. A. L. Lewis, Professor R. Meldola, Mr. F. W. Rudler, Rev. T. R. R. Stebbing, and the President and General Officers of the Association.	20 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee
SECTION A.—MATHEMATICS AND PHYSICS.	
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements.	*Chairman.*—Lord Rayleigh. *Secretary.*—Dr. R. T. Glazebrook. Professors J. Perry and W. G. Adams, Dr. G. Carey Foster, Sir Oliver Lodge, Dr. A. Muirhead, Sir W. H. Preece, Professor A. Schuster, Dr. J. A. Fleming, Professor Sir J. J. Thomson, Dr. W. N. Shaw, Dr. J. T. Bottomley, Rev. T. C. Fitzpatrick, Dr. G. Johnstone Stoney, Professor S. P. Thompson, Mr. J. Rennie, Principal E. H. Griffiths, Sir Arthur Rücker, Professor H. L. Callendar, and Messrs. G. Matthey, A. P. Trotter, T. Mather, and F. E. Smith.
To continue the Magnetic Survey of South Africa commenced by Professors Beattie and Morrison.	*Chairman.*—Sir David Gill. *Secretary.*—Professor J. C. Beattie. Mr. S. S. Hough, Professor Morrison, and Professor A. Schuster.
The further Tabulation of Bessel Functions.	*Chairman.*—Professor M. J. M. Hill. *Secretary.*—Dr. L. N. G. Filon. Professor Alfred Lodge and Mr. J. W. Nicholson.
To report upon the provision for the Study of Astronomy, Meteorology (including Atmospheric Electricity), and Geophysics in the Universities of the British Empire.	*Chairman.*—Sir Arthur Rücker. *Secretary.*—Professor A. E. H. Love. Sir Oliver Lodge, Professors C. G. Knott, E. Rutherford, A. Schuster, Sir J. J. Thomson, and E. T. Whittaker, Drs. W. G. Duffield and G. T. Walker, and Mr. R. T. A. Innes.
SECTION B.—CHEMISTRY.	
The Study of Isomorphous Sulphonic Derivatives of Benzene.	*Chairman.*—Professor H. A. Miers. *Secretary.*—Professor H. E. Armstrong. Professors W. P. Wynne and W. J. Pope.
SECTION C.—GEOLOGY.	
To determine the precise Significance of Topographical and Geological Terms used locally in South Africa.	*Chairman.*—Mr. G. W. Lamplugh. *Secretary.*—Dr. F. H. Hatch. Dr. G. Corstorphine and Messrs. A. Du Toit, A. P. Hall, G. Kynaston, F. P. Mennell, and A. W. Rogers.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
Section D.—ZOOLOGY.	
To continue the Investigation of the Zoology of the Sandwich Islands, with power to co-operate with the Committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance in their investigations as may be offered by the Hawaiian Government or the Trustees of the Museum at Honolulu. The Committee to have power to dispose of specimens where advisable.	*Chairman.*—Dr. F. Du Cane Godman. *Secretary.*—Dr. David Sharp. Professor S. J. Hickson, Dr. P. L. Sclater, and Mr. Edgar A. Smith.
To summon meetings in London or elsewhere for the consideration of matters affecting the interests of Zoology or Zoologists, and to obtain by correspondence the opinion of Zoologists on matters of a similar kind, with power to raise by subscription from each Zoologist a sum of money for defraying current expenses of the Organisation.	*Chairman.*—Sir E. Ray Lankester. *Secretary.*—Professor S. J. Hickson. Professors G. C. Bourne, J. Cossar Ewart, M. Hartog, W. A. Herdman, and J. Graham Kerr, Mr. O. H. Latter, Professor Minchin, Dr. P. C. Mitchell, Professors C. Lloyd Morgan, E. B. Poulton, and A. Sedgwick, Mr. A. E. Shipley, and Rev. T. R. R. Stebbing.
To nominate competent naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.	*Chairman* and *Secretary.*—Professor A. Dendy. Sir E. Ray Lankester, Professor A. Sedgwick, Professor Sydney H. Vines, and Mr. E. S. Goodrich.
To enable Dr. J. W. Jenkinson to continue his Researches on the Influence of Salt and other Solutions on the Development of the Frog.	*Chairman.*—Professor G. C. Bourne. *Secretary.*—Dr. J. W. Jenkinson. Professor S. J. Hickson and Mr. E. S. Goodrich.
To investigate the biological problems incidental to the Inniskea Whaling Station.	*Chairman.*—Dr. A. E. Shipley. *Secretary.*—Mr. J. Stanley Gardiner. Professor W. A. Herdman, Rev. W. Spotswood Green, Mr. E. S. Goodrich, Dr. H. W. Marett Tims, and Mr. R. M. Barrington.
Section H.—ANTHROPOLOGY.	
The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. H. S. Kingsford. Dr. G. A. Auden, Mr. E. Heawood, and Professor J. L. Myres.
To organise Anthropometric Investigation in the British Isles.	*Chairman.*—Professor A. Thomson. *Secretary.*—Mr. J. Gray. Dr. F. C. Shrubsall.
To conduct Archæological and Ethnological Investigations in Sardinia.	*Chairman.*—Mr. D. G. Hogarth. *Secretary.*—Professor R. C. Bosanquet. Dr. T. Ashby, Dr. W. L. H. Duckworth, Professor J. L. Myres, and Dr. F. C. Shrubsall.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
To report upon Archæological Investigations in British East Africa.	*Chairman.*—Mr. D. G. Hogarth. *Secretary.*—Dr. A. C. Haddon. Mr. H. Balfour, Mr. C. T. Currelly, Dr. H. O. Forbes, and Professor J. L. Myres.
To establish a system of measuring Mental Characters.	*Chairman.*—Dr. W. McDougall. *Secretary.*—Mr. J. Gray. Miss Cooper, Dr. Spearman, Dr. C. S. Myers, Dr. W. H. R. Rivers, Dr. W. G. Smith, and Dr. C. W. Kimmins.
Ethnographic Survey of Canada.	*Chairman.*—Rev. Dr. G. Bryce. *Secretary.*—Mr. E. S. Hartland. Dr. P. H. Bryce, Mr. C. Hill-Tout, Mr. B. Sulter, Professor J. L. Myres, Dr. A. C. Haddon, Dr. F. C. Shrubsall, Professor H. Montgomery, Mr. A. F. Hunter, Dr. J. Maclean, and the Hon. David Laird.

Section I.—PHYSIOLOGY.

The Effect of Climate upon Health and Disease.	*Chairman.*—Sir T. Lauder Brunton. *Secretaries.*—Mr. J. Barcroft and Lieut.-Col. Simpson. Colonel Sir D. Bruce, Dr. S. G. Campbell, Sir Kendal Franks, Professor J. G. McKendrick, Sir A. Mitchell, Dr. C. F. K. Murray, Dr. Porter, Dr. J. L. Todd, Professor Sims Woodhead, and the Heads of the Tropical Schools of Liverpool, London, and Edinburgh.

Section K.—BOTANY.

To carry out the scheme for the Registration of Negatives of Botanical Photographs.	*Chairman.*—Professor F. W. Oliver. *Secretary.*—Professor F. E. Weiss. Dr. W. G. Smith, Mr. A. G. Tansley, Dr. T. W. Woodhead, and Professor R. H. Yapp.

Section L.—EDUCATIONAL SCIENCE.

To take notice of, and report upon changes in, Regulations—whether Legislative, Administrative, or made by Local Authorities — affecting Secondary Education.	*Chairman.*—Sir Philip Magnus. *Secretary.*—Professor H. E. Armstrong. Sir William Bousfield, Mr. S. H. Butcher, Sir Henry Craik, Principal Griffiths, Sir Horace Plunkett, and Professor M. E. Sadler.
To inquire into and report upon the methods and results of research into the Mental and Physical Factors involved in Education.	*Chairman.*—Professor J. J. Findlay. *Secretary.*—Professor J. A. Green. Professors J. Adams and E. P. Culverwell, Mr. G. F. Daniell, Miss B. Foxley, Professor R. A. Gregory, Dr. C. W. Kimmins, Dr. T. P. Nunn, Dr. Spearman, Miss L. Edna Walter, and Dr. F. Warner.
To inquire into the Curricula and Educational Organisation of Industrial and Poor Law Schools with special reference to Day Industrial Schools.	*Chairman.*—Mr. W. D. Eggar. *Secretary.*—Mrs. W. N. Shaw. Mr. J. L. Holland and Dr. C. W. Kimmins.

Communications ordered to be printed in extenso.

Anode Rays and their Spectra, by Dr. O. Reichenheim.

On Threefold-emission Spectra of Solid Aromatic Compounds, by Dr. E. Goldstein.

Some Properties of Light of very short Wave-lengths, by Professor T. Lyman.

Report on Combustion, by Professor W. A. Bone.

Discussion on Wheat (Joint Meeting, Sections B and K and Sub-Section K).

The Development of Wheat Culture in North America, by Professor A. P. Brigham.

Agricultural Development in North-West Canada, by Professor J. Mavor.

The Engineering Works of the Panama Canal, by Colonel Goethals.

Resolutions referred to the Council for consideration, and, if desirable, for action.

From the General Committee.

(i) That the Council be asked to consider the relationship of the Sections generally, and the possible desirability of a new subdivision and the incorporation of new subjects.

(ii) That, in any revision of the organisation of the Association, full recognition be given to the importance of Agricultural Science.

From Section H.

I.

That the Council be recommended to represent to the Dominion Government :—

1. That it is essential to scientific knowledge of the early history of Canada that full and accurate records should be obtained of the physical character, geographical distribution and migrations, languages, social and political institutions, native arts, industries, and economic systems of the aboriginal peoples of the country;

2. That scientific knowledge of the principles of native design and handicraft is an essential preliminary to any development of native industries such as has already been found practicable, especially in the United States, in Mexico, and in India, and that such knowledge has also proved to be of material assistance in the creation of national schools of design among the white population;

3. That, in the rapid development of the country, the native population is inevitably losing its separate existence and characteristics;

4. That it is therefore ot urgent importance to initiate, without delay, systematic observations and records of native physical types, languages, beliefs, and customs, and to provide for the preservation of a complete collection of examples of native arts and industries in some central institution, and for public guardianship of prehistoric monuments such as village sites, burial grounds, mounds, and rock-carvings;

5. That the organisation necessary to secure these objects, and to render the results of these inquiries accessible to students and to the public, is such as might easily be provided in connection with the National Museum at Ottawa, which already includes many fine examples of aboriginal arts and manufactures, and might easily be made a centre for the scientific study of the physical types, languages, beliefs, and customs of the aboriginal peoples.

II.

To recommend the Council to urge the Dominion Government to include, in the schedules of the next Canadian Census, full inquiries as to precise place of origin, native language, previous status and occupation, year of immigration, and such other information as may be deemed of scientific value for the study of the effects of the Canadian environment upon immigrants of European origin.

Recommendations referred to the Council for consideration, and, if desirable, for action.

1. That the following Committee be authorised to receive contributions from sources other than the Association :—

'To conduct Explorations with a view to ascertaining the Age of Stone Circles.' (Section H.)

2. That the collection of the Anthropological Photographs printed by the Anthropological Photograph Committee, and all further Photographs received by them, be handed over to the custody of the Royal Anthropological Institute. (Section H.)

Synopsis of Grants of Money appropriated for Scientific Purposes by the General Committee at the Winnipeg Meeting, 1909. *The Names of Members entitled to call on the General Treasurer for the Grants are prefixed to the respective Research Committees.*

Recommended by Council.

	£	s.	d.
Gill, Sir D.—Measurement of Geodetic Arc in South Africa	100	0	0
Glazebrook, Dr. R. T.—Republication of Electrical Standards Reports	100	0	0

Mathematical and Physical Science.

*Turner, Professor H. H.—Seismological Observations	60	0	0
*Preece, Sir W. H.—Magnetic Observations at Falmouth	25	0	0
*Gill, Sir David—Establishing a Solar Observatory in Australia	50	0	0
Shaw, Dr. W. N.—Upper Atmosphere	25	0	0

Chemistry.

*Divers, Dr. E.—Study of Hydro-aromatic Substances	25	0	0
*Armstrong, Professor H. E.—Dynamic Isomerism	35	0	0
*Kipping, Professor F. S.—Transformation of Aromatic Nitroamines	15	0	0
*Kipping, Professor F. S.—Electroanalysis	10	0	0

Geology.

*Tiddeman, R. H.—Erratic Blocks	10	0	0
*Harker, Dr. A.—Crystalline Rocks of Anglesey	1	0	0
*Gregory, Professor J. W.—Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
*Lapworth, Professor C.—Palæozoic Rocks of Wales and the West of England	10	0	0
*Watts, Professor W. W.—Composition of Charnwood Rocks	2	0	0
*Watts, Professor W. W.—Igneous and Associated Rocks of Glensaul, &c.	15	0	0
*Gregory, Professor J. W.—South African Strata	5	0	0
*Geikie, Professor J.—Geological Photographs	10	0	0
Strahan, Dr. A.—Fossils of Midland Coalfields	25	0	0

Zoology.

*Hickson, Professor S. J.—Table at the Zoological Station at Naples	75	0	0
*Woodward, Dr. H.—Index Animalium	75	0	0
Carried forward	£683	0	0

* Reappointed.

	£	s.	d.
Brought forward	683	0	0

Zoology (continued).

*Herdman, Professor W. A.—Heredity Experiments	15	0	0
*Shipley, Dr. A. E.—Feeding Habits of British Birds	5	0	0
Vincent, Professor Swale—Prairie Fauna of Canada	15	0	0

Economic Science and Statistics.

*Palgrave, R. H. Inglis—Gold Coinage in Circulation in the United Kingdom	6	0	0
*Cannan, Professor E.—Amount and Distribution of Income below the Income-tax Exemption Limit	15	0	0

Engineering.

*Preece, Sir W. H.—Gaseous Explosions	75	0	0

Anthropology.

*Munro, Dr. R.—Lake Villages in the neighbourhood of Glastonbury	5	0	0
*Myres, Professor J. L.—Excavations on Roman Sites in Britain	5	0	0
*Read, C. H.—Age of Stone Circles	30	0	0
*Read, C. H.—Anthropological Notes and Queries	40	0	0
*Hogarth, D. G.—Researches in Crete	70	0	0
Ridgeway, Professor W.—Neolithic Sites in Northern Greece	5	0	0

Physiology.

*Schäfer, Professor E. A.—The Ductless Glands	40	0	0
*Sherrington, Professor C. S.—Body Metabolism in Cancer	20	0	0
*Hickson, Professor S. J.—Table at the Zoological Station at Naples	25	0	0
Waller, Professor A. D.—Anæsthetics	25	0	0
*Starling, Professor E. H.—Tissue Metabolism	25	0	0
*Sherrington, Professor C. S.—Mental and Muscular Fatigue	20	0	0
Waller, Dr. A. D.—Electromotive Phenomena in Plants	10	0	0
Starling, Professor E. H.—Dissociation of Oxy-Hæmoglobin	15	0	0

Botany.

*Scott, Dr. D. H.—Structure of Fossil Plants	10	0	0
*Darwin, Dr. F.—Experimental Study of Heredity	30	0	0
*Blackman, Dr. F. F.—Symbiosis between Turbellarian Worms and Algæ	5	0	0
*Johnson, Professor T.—Survey of Clare Island	30	0	0
Carried forward	£1224	0	0

* Reappointed.

	£	s.	d.
Brought forward	1224	0	0
Education.			
*Magnus, Sir P.—Studies suitable for Elementary Schools ...	5	0	0
Corresponding Societies Committee.			
*Whitaker, W.—For Preparation of Report	20	0	0
Total	£1249	0	0

* Reappointed.

Annual Meetings, 1910 *and* 1911.

The Annual Meeting of the Association in 1910 will be held at Sheffield, commencing August 31 ; in 1911 at Portsmouth.

PRESIDENT'S ADDRESS.

ADDRESS

BY

Professor Sir J. J. THOMSON, M.A., LL.D., D.Sc., F.R.S.,

PRESIDENT.

Twenty-five years ago a great change was made in the practice of the British Association. From the foundation of our Society until 1884 its meetings had always been held in the British Isles; in that year, however, the Association met in Montreal, and a step was taken which changed us from an Insular into an Imperial Association. For this change, which now I think meets with nothing but approval, Canada is mainly responsible. Men of science welcome it for the increased opportunities it gives them of studying under the most pleasant and favourable conditions different parts of our Empire, of making new friends; such meetings as these not only promote the progress of science but also help to strengthen the bonds which bind together the different portions of the King's Dominions.

This year, for the third time in a quarter of a century, we are meeting in Canada. As if to give us an object-lesson in the growth of Empire, you in Winnipeg took the opportunity at our first meeting in Canada in 1884 to invite our members to visit Manitoba and see for themselves the development of the Province at that time. Those who were fortunate enough to be your guests then as well as now are confronted with a change which must seem to them unexampled and almost incredible. Great cities have sprung up, immense areas have been converted from prairies to prosperous farms, flourishing industries have been started, and the population has quadrupled. As the President of a scientific Association I hope I may be pardoned if I point out that even the enterprise and energy of your people and the richness of your country would have been powerless to effect this change without the resources placed at their disposal by the labours of men of science.

The eminence of my predecessors in the chair at the meetings of the British Association in Canada makes my task this evening a difficult one. The meeting at Montreal was presided over by Lord Rayleigh, who, like Lord Kelvin, his colleague in the chair of Section A at that meeting, has left the lion's mark on every department of physics, and who has shown that, vast as is the empire of physics, there are still men who can extend its frontiers in all of the many regions under its sway. It has been my lot to succeed Lord Rayleigh in other offices as well as this, and I know how difficult a man he is to follow.

The President of the second meeting in Canada—that held in 1897 at Toronto—was Sir John Evans, one of those men who, like Boyle, Cavendish, Darwin, Joule, Spottiswoode, and Huggins, have, from their own resources and without the aid derived from official positions or from the universities, made memorable contributions to science: such men form one of the characteristic features of British science. May we not hope that, as the knowledge of science and the interest taken in it increase, more of the large number of men of independent means in our country may be found working for the advancement of science, and thereby rendering services to the community no less valuable than the political, philanthropic, and social work at which many of them labour with so much zeal and success?

I can, however, claim to have some experience of at any rate one branch of Canadian science, for it has been my privilege to receive at the Cavendish Laboratory many students from your universities. Some of these have been holders of what are known as the 1851 scholarships. These scholarships are provided from the surplus of the Great Exhibition of 1851, and are placed at the disposal of most of the younger universities in the British Empire, to enable students to devote themselves for two or three years to original research in various branches of science. I have had many opportunities of seeing the work of these scholars, and I should like to put on record my opinion that there is no educational endowment in the country which has done or is doing better work.

I have had, as I said, the privilege of having as pupils students from your universities as well as from those of New Zealand, Australia, and the United States, and have thus had opportunities of comparing the effect on the best men of the educational system in force at your universities with that which prevails in the older English universities. Well, as the result, I have come to the conclusion that there is a good deal in the latter system which you have been wise not to imitate. The chief evil from which we at Cambridge suffer and which you have avoided is, I am convinced, the excessive competition for scholarships which confronts our students at almost every stage of their education. You may form some estimate of the prevalence of these scholarships if I tell you that the colleges in the University of Cambridge alone give

more than 35,000*l.* a year in scholarships to undergraduates, and I suppose the case is much the same at Oxford. The result of this is that preparation for these scholarships dominates the education of the great majority of the cleverer boys who come to these universities, and indeed in some quarters it seems to be held that the chief duty of a schoolmaster, and the best test of his efficiency, is to make his boys get scholarships. The preparation for the scholarship too often means that about two years before the examination the boy begins to specialise, and from the age of sixteen does little else than the subject, be it mathematics, classics, or natural science, for which he wishes to get a scholarship; then, on entering the university, he spends three or four years studying the same subject before he takes his degree, when his real life-work ought to begin. How has this training fitted him for this work? I will take the case in which the system might perhaps be expected to show to greatest advantage, when his work is to be original research in the subject he has been studying. He has certainly acquired a very minute acquaintance with his subject—indeed, the knowledge possessed by some of the students trained under this system is quite remarkable, much greater than that of any other students I have ever met. But though he has acquired knowledge, the effect of studying one subject, and one subject only, for so long a time is too often to dull his enthusiasm for it, and he begins research with much of his early interest and keenness evaporated. Now there is hardly any quality more essential to success in research than enthusiasm. Research is difficult, laborious, often disheartening. The carefully designed apparatus refuses to work, it develops defects which may take months of patient work to rectify, the results obtained may appear inconsistent with each other and with every known law of Nature, sleepless nights and laborious days may seem only to make the confusion more confounded, and there is nothing for the student to do but to take for his motto 'It's dogged as does it,' and plod on, comforting himself with the assurance that when success does come, the difficulties he has overcome will increase the pleasure—one of the most exquisite men can enjoy—of getting some conception which will make all that was tangled, confused, and contradictory clear and consistent. Unless he has enthusiasm to carry him on when the prospect seems almost hopeless and the labour and strain incessant, the student may give up his task and take to easier, though less important, pursuits.

I am convinced that no greater evil can be done to a young man than to dull his enthusiasm. In a very considerable experience of students of physics beginning research, I have met with more—many more—failures from lack of enthusiasm and determination than from any lack of knowledge or of what is usually known as cleverness.

This continual harping from an early age on one subject, which is so efficient in quenching enthusiasm, is much encouraged by the

practice of the colleges to give scholarships for proficiency in one subject alone. I went through a list of the scholarships awarded in the University of Cambridge last winter, and, though there were 202 of them, I could only find three cases in which it was specified that the award was made for proficiency in more than one subject.

The premature specialisation fostered by the preparation for these scholarships injures the student by depriving him of adequate literary culture, while when it extends, as it often does, to specialisation in one or two branches of science, it retards the progress of science by tending to isolate one science from another. The boundaries between the sciences are arbitrary, and tend to disappear as science progresses. The principles of one science often find most striking and suggestive illustrations in the phenomena of another. Thus, for example, the physicist finds in astronomy that effects he has observed in the laboratory are illustrated on the grand scale in the sun and stars. No better illustration of this could be given than Professor Hale's recent discovery of the Zeeman effect in the light from sunspots; in chemistry, too, the physicist finds in the behaviour of whole series of reactions illustrations of the great laws of thermodynamics, while if he turns to the biological sciences he is confronted by problems, mostly unsolved, of unsurpassed interest. Consider for a moment the problem presented by almost any plant—the characteristic and often exquisite detail of flower, leaf, and habit—and remember that the mechanism which controls this almost infinite complexity was once contained in a seed perhaps hardly large enough to be visible. We have here one of the most entrancing problems in chemistry and physics it is possible to conceive.

Again, the specialisation prevalent in schools often prevents students of science from acquiring sufficient knowledge of mathematics; it is true that most of those who study physics do some mathematics, but I hold that, in general, they do not do enough, and that they are not as efficient physicists as they would be if they had a wider knowledge of that subject. There seems at present a tendency in some quarters to discourage the use of mathematics in physics; indeed, one might infer, from the statements of some writers in quasi-scientific journals, that ignorance of mathematics is almost a virtue. If this is so, then surely of all the virtues this is the easiest and most prevalent.

I do not for a moment urge that the physicist should confine himself to looking at his problems from the mathematical point of view; on the contrary, I think a famous French mathematician and physicist was guilty of only slight exaggeration when he said that no discovery was really important or properly understood by its author unless and until he could explain it to the first man he met in the street.

But two points of view are better than one, and the physicist who is also a mathematician possesses a most powerful instrument for scientific research with which many of the greatest discoveries have been

made; for example, electric waves were discovered by mathematics long before they were detected in the laboratory. He has also at his command a language clear, concise, and universal, and there is no better way of detecting ambiguities and discrepancies in his ideas than by trying to express them in this language. Again, it often happens that we are not able to appreciate the full significance of some physical discovery until we have subjected it to mathematical treatment, when we find that the effect we have discovered involves other effects which have not been detected, and we are able by this means to duplicate the discovery. Thus James Thomson, starting from the fact that ice floats on water, showed that it follows by mathematics that ice can be melted and water prevented from freezing by pressure. This effect, which was at that time unknown, was afterwards verified by his brother, Lord Kelvin. Multitudes of similar duplication of physical discoveries by mathematics could be quoted.

I have been pleading in the interests of physics for a greater study of mathematics by physicists. I would also plead for a greater study of physics by mathematicians in the interest of pure mathematics.

The history of pure mathematics shows that many of the most important branches of the subject have arisen from the attempts made to get a mathematical solution of a problem suggested by physics. Thus the differential calculus arose from attempts to deal with the problem of moving bodies. Fourier's theorem resulted from attempts to deal with the vibrations of strings and the conduction of heat; indeed, it would seem that the most fruitful crop of scientific ideas is produced by cross-fertilisation between the mind and some definite fact, and that the mind by itself is comparatively unproductive.

I think, if we could trace the origin of some of our most comprehensive and important scientific ideas, it would be found that they arose in the attempt to find an explanation of some apparently trivial and very special phenomenon; when once started the ideas grew to such generality and importance that their modest origin could hardly be suspected. Water vapour we know will refuse to condense into rain unless there are particles of dust to form nuclei; so an idea before taking shape seems to require a nucleus of solid fact round which it can condense.

I have ventured to urge the closer union between mathematics and physics, because I think of late years there has been some tendency for these sciences to drift apart, and that the workers in applied mathematics are relatively fewer than they were some years ago. This is no doubt due to some extent to the remarkable developments made in the last few years in experimental physics on the one hand and in the most abstract and metaphysical parts of pure mathematics on the other. The fascination of these has drawn workers to the frontiers of these regions who would otherwise have worked nearer the junction of the

two. In part, too, it may be due to the fact that the problems with which the applied mathematician has to deal are exceedingly difficult, and many may have felt that the problems presented by the older physics have been worked over so often by men of the highest genius that there was but little chance of any problem which they could have any hope of solving being left.

But the newer developments of physics have opened virgin ground which has not yet been worked over and which offers problems to the mathematician of great interest and novelty—problems which will suggest and require new methods of attack, the development of which will advance pure mathematics as well as physics.

I have alluded to the fact that pure mathematicians have been indebted to the study of concrete problems for the origination of some of their most valuable conceptions; but though no doubt pure mathematicians are in many ways very exceptional folk, yet in this respect they are very human. Most of us need to tackle some definite difficulty before our minds develop whatever powers they may possess. This is true for even the youngest of us, for our schoolboys and schoolgirls, and I think the moral to be drawn from it is that we should aim at making the education in our schools as little bookish and as practical and concrete as possible.

I once had an illustration of the power of the concrete in stimulating the mind which made a very lasting impression upon me. One of my first pupils came to me with the assurance from his previous teacher that he knew little and cared less about mathematics, and that he had no chance of obtaining a degree in that subject. For some time I thought this estimate was correct, but he happened to be enthusiastic about billiards, and when we were reading that part of mechanics which deals with the collision of elastic bodies I pointed out that many of the effects he was constantly observing were illustrations of the subject we were studying. From that time he was a changed man. He had never before regarded mathematics as anything but a means of annoying innocent undergraduates; now, when he saw what important results it could obtain, he became enthusiastic about it, developed very considerable mathematical ability, and, though he had already wasted two out of his three years at college, took a good place in the Mathematical Tripos.

It is possible to read books, to pass examinations, without the higher qualities of the mind being called into play. Indeed, I doubt if there is any process in which the mind is more quiescent than in reading without interest. I might appeal to the widespread habit of reading in bed as a prevention of insomnia as a proof of this. But it is not possible for a boy to make a boat or for a girl to cook a dinner without using their brains. With practical things the difficulties have to be surmounted, the boat must be made watertight, the dinner must

be cooked, while in reading there is always the hope that the difficulties which have been slurred over will not be set in the examination.

I think it was Helmholtz who said that often in the course of a research more thought and energy were spent in reducing a refractory piece of brass to order than in devising the method or planning the scheme of campaign. This constant need for thought and action gives to original research in any branch of experimental science great educational value even for those who will not become professional men of science. I have had considerable experience with students beginning research in experimental physics, and I have always been struck by the quite remarkable improvement in judgment, independence of thought and maturity produced by a year's research. Research develops qualities which are apt to atrophy when the student is preparing for examinations, and, quite apart from the addition of new knowledge to our store, is of the greatest importance as a means of education.

It is the practice in many universities to make special provision for the reception of students from other universities who wish to do original research or to study the more advanced parts of their subject, and considerable numbers of such students migrate from one university to another. I think it would be a good thing if this practice were to extend to students at an earlier stage in their career; especially should I like to see a considerable interchange of students between the universities in the Mother Country and those in the Colonies.

I am quite sure that many of our English students, especially those destined for public life, could have no more valuable experience than to spend a year in one or other of your universities, and I hope some of your students might profit by a visit to ours.

I can think of nothing more likely to lead to a better understanding of the feelings, the sympathies, and, what is not less important, the prejudices, of one country by another than by the youths of those countries spending a part of their student life together. Undergraduates as a rule do not wear a mask either of politeness or any other material, and have probably a better knowledge of each other's opinions and points of view—in fact, know each other better than do people of riper age. To bring this communion of students about there must be co-operation between the universities throughout the Empire; there must be recognition of each other's examinations, residence, and degrees. Before this can be accomplished there must, as my friend Mr. E. B. Sargant pointed out in a lecture given at the McGill University, be co-operation and recognition between the universities in each part of the Empire. I do not mean for a moment that all universities in a country should be under one government. I am a strong believer in the individuality of universities, but I do not think this is in any way inconsistent with the policy of an open door from one university to every other in the Empire.

It has usually been the practice of the President of this Association to give some account of the progress made in the last few years in the branch of science which he has the honour to represent.

I propose this evening to follow that precedent and to attempt to give a very short account of some of the more recent developments of physics, and the new conceptions of physical processes to which they have led.

The period which has elapsed since the Association last met in Canada has been one of almost unparalleled activity in many branches of physics, and many new and unsuspected properties of matter and electricity have been discovered. The history of this period affords a remarkable illustration of the effect which may be produced by a single discovery; for it is, I think, to the discovery of the Röntgen rays that we owe the rapidity of the progress which has recently been made in physics. A striking discovery like that of the Röntgen rays acts much like the discovery of gold in a sparsely populated country; it attracts workers who come in the first place for the gold, but who may find that the country has other products, other charms, perhaps even more valuable than the gold itself. The country in which the gold was discovered in the case of the Röntgen rays was the department of physics dealing with the discharge of electricity through gases, a subject which, almost from the beginning of electrical science, had attracted a few enthusiastic workers, who felt convinced that the key to unlock the secret of electricity was to be found in a vacuum tube. Röntgen, in 1895, showed that when electricity passed through such a tube, the tube emitted rays which could pass through bodies opaque to ordinary light; which could, for example, pass through the flesh of the body and throw a shadow of the bones on a suitable screen. The fascination of this discovery attracted many workers to the subject of the discharge of electricity through gases, and led to great improvements in the instruments used in this type of research. It is not, however, to the power of probing dark places, important though this is, that the influence of Röntgen rays on the progress of science has mainly been due; it is rather because these rays make gases, and, indeed, solids and liquids, through which they pass conductors of electricity. It is true that before the discovery of these rays other methods of making gases conductors were known, but none of these was so convenient for the purposes of accurate measurement.

The study of gases exposed to Röntgen rays has revealed in such gases the presence of particles charged with electricity; some of these particles are charged with positive, others with negative electricity.

The properties of these particles have been investigated; we know the charge they carry, the speed with which they move under an electric force, the rate at which the oppositely charged ones recombine, and these investigations have thrown a new light not only on electricity, but also on the structure of matter.

We know from these investigations that electricity, like matter, is molecular in structure, that just as a quantity of hydrogen is a collection of an immense number of small particles called molecules, so a charge of electricity is made up of a great number of small charges, each of a perfectly definite and known amount.

Helmholtz said in 1880 that in his opinion the evidence in favour of the molecular constitution of electricity was even stronger than that in favour of the molecular constitution of matter. How much stronger is that evidence now, when we have measured the charge on the unit and found it to be the same from whatever source the electricity is obtained. Nay, further, the molecular theory of matter is indebted to the molecular theory of electricity for the most accurate determination of its fundamental quantity, the number of molecules in any given quantity of an elementary substance.

The great advantage of the electrical methods for the study of the properties of matter is due to the fact that whenever a particle is electrified it is very easily identified, whereas an uncharged molecule is most elusive; and it is only when these are present in immense numbers that we are able to detect them. A very simple calculation will illustrate the difference in our power of detecting electrified and unelectrified molecules. The smallest quantity of unelectrified matter ever detected is probably that of neon, one of the inert gases of the atmosphere. Professor Strutt has shown that the amount of neon in $\frac{1}{20}$ of a cubic centimetre of the air at ordinary pressures can be detected by the spectroscope; Sir William Ramsay estimates that the neon in the air only amounts to one part of neon in 100,000 parts of air, so that the neon in $\frac{1}{20}$ of a cubic centimetre of air would only occupy at atmospheric pressure a volume of half a millionth of a cubic centimetre. When stated in this form the quantity seems exceedingly small, but in this small volume there are about ten million million molecules. Now the population of the earth is estimated at about fifteen hundred millions, so that the smallest number of molecules of neon we can identify is about 7,000 times the population of the earth. In other words, if we had no better test for the existence of a man than we have for that of an unelectrified molecule we should come to the conclusion that the earth is uninhabited. Contrast this with our power of detecting electrified molecules. We can by the electrical method, even better by the cloud method of C. T. R. Wilson, detect the presence of three or four charged particles in a cubic centimetre. Rutherford has shown that we can detect the presence of a single α particle. Now the α particle is a charged atom of helium; if this atom had been uncharged we should have required more than a million million of them, instead of one, before we should have been able to detect them.

We may I think conclude, since electrified particles can be studied with so much greater ease than unelectrified ones, that we shall obtain a knowledge of the ultimate structure of electricity before we arrive at

a corresponding degree of certainty with regard to the structure of matter.

We have already made considerable progress in the task of discovering what the structure of electricity is. We have known for some time that of one kind of electricity—the negative—and a very interesting one it is. We know that negative electricity is made up of units all of which are of the same kind; that these units are exceedingly small compared with even the smallest atom, for the mass of the unit is only $\frac{1}{1700}$ part of the mass of an atom of hydrogen; that its radius is only 10^{-13} centimetre, and that these units, 'corpuscles' as they have been called, can be obtained from all substances. The size of these corpuscles is on an altogether different scale from that of atoms; the volume of a corpuscle bears to that of the atom about the same relation as that of a speck of dust to the volume of this room. Under suitable conditions they move at enormous speeds which approach in some instances the velocity of light.

The discovery of these corpuscles is an interesting example of the way Nature responds to the demands made upon her by mathematicians. Some years before the discovery of corpuscles it had been shown by a mathematical investigation that the mass of a body must be increased by a charge of electricity. This increase, however, is greater for small bodies than for large ones, and even bodies as small as atoms are hopelessly too large to show any appreciable effect; thus the result seemed entirely academic. After a time corpuscles were discovered, and these are so much smaller than the atom that the increase in mass due to the charge becomes not merely appreciable, but so great that, as the experiments of Kaufmann and Bucherer have shown, the whole of the mass of the corpuscle arises from its charge.

We know a great deal about negative electricity; what do we know about positive electricity? Is positive electricity molecular in structure? Is it made up into units, each unit carrying a charge equal in magnitude though opposite in sign to that carried by a corpuscle? Does, or does not, this unit differ, in size and physical properties, very widely from the corpuscle? We know that by suitable processes we can get corpuscles out of any kind of matter, and that the corpuscles will be the same from whatever source they may be derived. Is a similar thing true for positive electricity? Can we get, for example, a positive unit from oxygen of the same kind as that we get from hydrogen?

For my own part, I think the evidence is in favour of the view that we can, although the nature of the unit of positive electricity makes the proof much more difficult than for the negative unit.

In the first place we find that the positive particles—'canalstrahlen' is their technical name—discovered by our distinguished guest, Dr. Goldstein, which are found when an electric discharge passes through a highly rarefied gas, are, when the pressure is very low, the same, whatever may

have been the gas in the vessel to begin with. If we pump out the gas until the pressure is too low to allow the discharge to pass, and then introduce a small quantity of gas and restart the discharge, the positive particles are the same whatever kind of gas may have been introduced.

I have, for example, put into the exhausted vessel oxygen, argon, helium, the vapour of carbon tetrachloride, none of which contain hydrogen, and found the positive particles to be the same as when hydrogen was introduced.

Some experiments made lately by Wellisch, in the Cavendish Laboratory, strongly support the view that there is a definite unit of positive electricity independent of the gas from which it is derived; these experiments were on the velocity with which positive particles move through mixed gases. If we have a mixture of methyl-iodide and hydrogen exposed to Röntgen rays, the effect of the rays on the methyl-iodide is so much greater than on the hydrogen that, even when the mixture contains only a small percentage of methyl-iodide, practically all the electricity comes from this gas, and not from the hydrogen.

Now if the positive particles were merely the residue left when a corpuscle had been abstracted from the methyl-iodide, these particles would have the dimensions of a molecule of methyl-iodide; this is very large and heavy, and would therefore move more slowly through the hydrogen molecules than the positive particles derived from hydrogen itself, which would, on this view, be of the size and weight of the light hydrogen molecules. Wellisch found that the velocities of both the positive and negative particles through the mixture were the same as the velocities through pure hydrogen, although in the one case the ions had originated from methyl-iodide and in the other from hydrogen; a similar result was obtained when carbon tetrachloride, or mercury methyl, was used instead of methyl-iodide. These and similar results lead to the conclusion that the atom of the different chemical elements contain definite units of positive as well as of negative electricity, and that the positive electricity, like the negative, is molecular in structure.

The investigations made on the unit of positive electricity show that it is of quite a different kind from the unit of negative; the mass of the negative unit is exceedingly small compared with any atom; the only positive units that up to the present have been detected are quite comparable in mass with the mass of an atom of hydrogen, in fact they seem equal to it. This makes it more difficult to be certain that the unit of positive electricity has been isolated, for we have to be on our guard against its being a much smaller body attached to the hydrogen atoms which happen to be present in the vessel. If the positive units have a much greater mass than the negative ones, they ought not to be so easily deflected by magnetic forces when moving at equal speeds; and in general the insensibility of the positive particles to the influence of a magnet is very marked; though there are cases when the positive

particles are much more readily deflected, and these have been interpreted as proving the existence of positive units comparable in mass with the negative ones. I have found, however, that in these cases the positive particles are moving very slowly, and that the ease with which they are deflected is due to the smallness of the velocity and not to that of the mass. It should, however, be noted that M. Jean Becquerel has observed in the absorption spectra of some minerals, and Professor Wood in the rotation of the plane of polarisation by sodium vapour, effects which could be explained by the presence in the substances of positive units comparable in mass with corpuscles. This, however, is not the only explanation which can be given of these effects, and at present the smallest positive electrified particles of which we have direct experimental evidence have masses comparable with that of an atom of hydrogen.

A knowledge of the mass and size of the two units of electricity, the positive and the negative, would give us the material for constructing what may be called a molecular theory of electricity, and would be a starting-point for a theory of the structure of matter; for the most natural view to take, as a provisional hypothesis, is that matter is just a collection of positive and negative units of electricity, and that the forces which hold atoms and molecules together, the properties which differentiate one kind of matter from another, all have their origin in the electrical forces exerted by positive and negative units of electricity, grouped together in different ways in the atoms of the different elements.

As it would seem that the units of positive and negative electricity are of very different sizes, we must regard matter as a mixture containing systems of very different types, one type corresponding to the small corpuscle, the other to the large positive unit.

Since the energy associated with a given charge is greater the smaller the body on which the charge is concentrated, the energy stored up in the negative corpuscles will be far greater than that stored up by the positive. The amount of energy which is stored up in ordinary matter in the form of the electrostatic potential energy of its corpuscles is, I think, not generally realised. All substances give out corpuscles, so that we may assume that each atom of a substance contains at least one corpuscle. From the size and the charge on the corpuscle, both of which are known, we find that each corpuscle has 8×10^{-7} ergs of energy; this is on the supposition that the usual expressions for the energy of a charged body hold when, as in the case of a corpuscle, the charge is reduced to one unit. Now in one gramme of hydrogen there are about 6×10^{23} atoms, so if there is only one corpuscle in each atom the energy due to the corpuscles in a gramme of hydrogen would be 48×10^{16} ergs, or 11×10^{9} calories. This is more than seven times the heat developed by one gramme of radium, or than that developed by the burning of five tons of coal. Thus we see that even ordinary matter

contains enormous stores of energy; this energy is fortunately kept fast bound by the corpuscles; if at any time an appreciable fraction were to get free, the earth would explode and become a gaseous nebula.

The matter of which I have been speaking so far is the material which builds up the earth, the sun, and the stars, the matter studied by the chemist, and which he can represent by a formula; this matter occupies, however, but an insignificant fraction of the universe, it forms but minute islands in the great ocean of the ether, the substance with which the whole universe is filled.

The ether is not a fantastic creation of the speculative philosopher; it is as essential to us as the air we breathe. For we must remember that we on this earth are not living on our own resources; we are dependent from minute to minute upon what we are getting from the sun, and the gifts of the sun are conveyed to us by the ether. It is to the sun that we owe not merely night and day, springtime and harvest, but it is the energy of the sun, stored up in coal, in waterfalls, in food, that practically does all the work of the world.

How great is the supply the sun lavishes upon us becomes clear when we consider that the heat received by the earth under a high sun and a clear sky is equivalent, according to the measurements of Langley, to about 7,000 horse-power per acre. Though our engineers have not yet discovered how to utilise this enormous supply of power, they will, I have not the slightest doubt, ultimately succeed in doing so; and when coal is exhausted and our water-power inadequate, it may be that this is the source from which we shall derive the energy necessary for the world's work. When that comes about, our centres of industrial activity may perhaps be transferred to the burning deserts of the Sahara, and the value of land determined by its suitability for the reception of traps to catch sunbeams.

This energy, in the interval between its departure from the sun and its arrival at the earth, must be in the space between them. Thus this space must contain something which, like ordinary matter, can store up energy, which can carry at an enormous pace the energy associated with light and heat, and which can, in addition, exert the enormous stresses necessary to keep the earth circling round the sun and the moon round the earth.

The study of this all-pervading substance is perhaps the most fascinating and important duty of the physicist.

On the electromagnetic theory of light, now universally accepted, the energy streaming to the earth travels through the ether in electric waves; thus practically the whole of the energy at our disposal has at one time or another been electrical energy. The ether must, then, be the seat of electrical and magnetic forces. We know, thanks to the genius of Clerk Maxwell, the founder and inspirer of modern electrical theory, the equations which express the relation between these forces,

and although for some purposes these are all we require, yet they do not tell us very much about the nature of the ether.

The interest inspired by equations, too, in some minds is apt to be somewhat Platonic; and something more grossly mechanical—a model, for example, is felt by many to be more suggestive and manageable, and for them a more powerful instrument of research, than a purely analytical theory.

Is the ether dense or rare? Has it a structure? Is it at rest or in motion? are some of the questions which force themselves upon us.

Let us consider some of the facts known about the ether. When light falls on a body and is absorbed by it, the body is pushed forward in the direction in which the light is travelling, and if the body is free to move it is set in motion by the light. Now it is a fundamental principle of dynamics that when a body is set moving in a certain direction, or, to use the language of dynamics, acquires momentum in that direction, some other mass must lose the same amount of momentum; in other words, the amount of momentum in the universe is constant. Thus when the body is pushed forward by the light some other system must have lost the momentum the body acquires, and the only other system available is the wave of light falling on the body; hence we conclude that there must have been momentum in the wave in the direction in which it is travelling. Momentum, however, implies mass in motion. We conclude, then, that in the ether through which the wave is moving there is mass moving with the velocity of light. The experiments made on the pressure due to light enable us to calculate this mass, and we find that in a cubic kilometre of ether carrying light as intense as sunlight is at the surface of the earth, the mass moving is only about one-fifty-millionth of a milligramme. We must be careful not to confuse this with the mass of a cubic kilometre of ether; it is only the mass moved when the light passes through it; the vast majority of the ether is left undisturbed by the light. Now, on the electromagnetic theory of light, a wave of light may be regarded as made up of groups of lines of electric force moving with the velocity of light; and if we take this point of view we can prove that the mass of ether per cubic centimetre carried along is proportional to the energy possessed by these lines of electric force per cubic centimetre, divided by the square of the velocity of light. But though lines of electric force carry some of the ether along with them as they move, the amount so carried, even in the strongest electric fields we can produce, is but a minute fraction of the ether in their neighbourhood.

This is proved by an experiment made by Sir Oliver Lodge in which light was made to travel through an electric field in rapid motion. If the electric field had carried the whole of the ether with it, the velocity of the light would have been increased by the velocity of the electric field. As a matter of fact no increase whatever could be detected, though it would have been registered if it had amounted to one-thousandth part of that of the field.

The ether carried along by a wave of light must be an exceedingly small part of the volume through which the wave is spread. Parts of this volume are in motion, but by far the greater part is at rest; thus in the wave front there cannot be uniformity, at some parts the ether is moving, at others it is at rest—in other words, the wave front must be more analogous to bright specks on a dark ground than to a uniformly illuminated surface.

The place where the density of the ether carried along by an electric field rises to its highest value is close to a corpuscle, for round the corpuscles are by far the strongest electric fields of which we have any knowledge. We know the mass of the corpuscle, we know from Kaufmann's experiments that this arises entirely from the electric charge, and is therefore due to the ether carried along with the corpuscle by the lines of force attached to it.

A simple calculation shows that one-half of this mass is contained in a volume seven times that of a corpuscle. Since we know the volume of the corpuscle as well as the mass, we can calculate the density of the ether attached to the corpuscle; doing so, we find it amounts to the prodigious value of about 5×10^{10}, or about 2,000 million times that of lead. Sir Oliver Lodge, by somewhat different considerations, has arrived at a value of the same order of magnitude.

Thus around the corpuscle ether must have an extravagant density: whether the density is as great as this in other places depends upon whether the ether is compressible or not. If it is compressible, then it may be condensed round the corpuscles, and there have an abnormally great density; if it is not compressible, then the density in free space cannot be less than the number I have just mentioned.

With respect to this point we must remember that the forces acting on the ether close to the corpuscle are prodigious. If the ether were, for example, an ideal gas whose density increased in proportion to the pressure, however great the pressure might be, then if, when exposed to the pressures which exist in some directions close to the corpuscle, it had the density stated above, its density under atmospheric pressure would only be about 8×10^{-16}, or a cubic kilometre would have a mass less than a gramme; so that instead of being almost incomparably denser than lead, it would be almost incomparably rarer than the lightest gas.

I do not know at present of any effect which would enable us to determine whether ether is compressible or not. And although at first sight the idea that we are immersed in a medium almost infinitely denser than lead might seem inconceivable, it is not so if we remember that in all probability matter is composed mainly of holes. We may, in fact, regard matter as possessing a bird-cage kind of structure in which the volume of the ether disturbed by the wires when the structure is moved is infinitesimal in comparison with the volume enclosed by them. If we do this, no difficulty arises from the great

density of the ether; all we have to do is to increase the distance between the wires in proportion as we increase the density of the ether.

Let us now consider how much ether is carried along by ordinary matter, and what effects this might be expected to produce.

The simplest electrical system we know, an electrified sphere, has attached to it a mass of ether proportional to its potential energy, and such that if the mass were to move with the velocity of light its kinetic energy would equal the electrostatic potential energy of the particle. This result can be extended to any electrified system, and it can be shown that such a system binds a mass of the ether proportional to its potential energy. Thus a part of the mass of any system is proportional to the potential energy of the system.

The question now arises, Does this part of the mass add anything to the weight of the body? If the ether were not subject to gravitational attraction it certainly would not; and even if the ether were ponderable, we might expect that as the mass is swimming in a sea of ether it would not increase the weight of the body to which it is attached. But if it does not, then a body with a large amount of potential energy may have an appreciable amount of its mass in a form which does not increase its weight, and thus the weight of a given mass of it may be less than that of an equal mass of some substance with a smaller amount of potential energy. Thus the weights of equal masses of these substances would be different. Now, experiments with pendulums, as Newton pointed out, enable us to determine with great accuracy the weights of equal masses of different substances. Newton himself made experiments of this kind, and found that the weights of equal masses were the same for all the materials he tried. Bessel, in 1830, made some experiments on this subject which are still the most accurate we possess, and he showed that the weights of equal masses of lead, silver, iron, brass did not differ by as much as one part in 60,000.

The substances tried by Newton and Bessel did not, however, include any of those substances which possess the marvellous power of radio-activity; the discovery of these came much later, and is one of the most striking achievements of modern physics.

These radio-active substances are constantly giving out large quantities of heat, presumably at the expense of their potential energy; thus when these substances reach their final non-radio-active state their potential energy must be less than when they were radio-active. Professor Rutherford's measurements show that the energy emitted by one gramme of radium in the course of its degradation to non-radio-active forms is equal to the kinetic energy of a mass of $\frac{1}{13}$th of a milligramme moving with the velocity of light.

This energy, according to the rule I have stated, corresponds to a mass of $\frac{1}{13}$th of a milligramme of the ether, and thus a gramme of radium in its radio-active state must have at least $\frac{1}{13}$th of a

milligramme more of ether attached to it than when it has been degraded into the non-radio-active forms. Thus if this ether does not increase the weight of the radium, the ratio of mass to weight for radium would be greater by about one part in 13,000 than for its non-radio-active products.

I attempted several years ago to find the ratio of mass to weight for radium by swinging a little pendulum, the bob of which was made of radium. I had only a small quantity of radium, and was not therefore able to attain any great accuracy. I found that the difference, if any, in the ratio of the mass to weight between radium and other substances was not more than one part in 2,000. Lately we have been using at the Cavendish Laboratory a pendulum whose bob was filled with uranium oxide. We have got good reasons for supposing that uranium is a parent of radium, so that the great potential energy and large ethereal mass possessed by the radium will be also in the uranium; the experiments are not yet completed. It is, perhaps, expecting almost too much to hope that the radio-active substances may add to the great services they have already done to science by furnishing the first case in which there is some differentiation in the action of gravity.

The mass of ether bound by any system is such that if it were to move with the velocity of light its kinetic energy would be equal to the potential energy of the system. This result suggests a new view of the nature of potential energy. Potential energy is usually regarded as essentially different from kinetic energy. Potential energy depends on the configuration of the system, and can be calculated from it when we have the requisite data; kinetic energy, on the other hand, depends upon the velocity of the system. According to the principle of the conservation of energy the one form can be converted into the other at a fixed rate of exchange, so that when one unit of one kind disappears a unit of the other simultaneously appears.

Now in many cases this rule is all that we require to calculate the behaviour of the system, and the conception of potential energy is of the utmost value in making the knowledge derived from experiment and observation available for mathematical calculation. It must, however, I think, be admitted that from the purely philosophical point of view it is open to serious objection. It violates, for example, the principle of continuity. When a thing changes from a state A to a different state B, the principle of continuity requires that it must pass through a number of states intermediate between A and B, so that the transition is made gradually and not abruptly. Now when kinetic energy changes into potential, although there is no discontinuity in the quantity of the energy, there is in its quality, for we do not recognise any kind of energy intermediate between that due to the motion and that due to the position of the system, and some portions of energy are supposed to change *per saltum* from the kinetic to the potential form. In the case of the transition of kinetic energy into heat energy in a gas, the discontinuity

has disappeared with a fuller knowledge of what the heat energy in a gas is due to. When we were ignorant of the nature of this energy, the transition from kinetic into thermal energy seemed discontinuous; but now we know that this energy is the kinetic energy of the molecules of which the gas is composed, so that there is no change in the type of energy when the kinetic energy of visible motion is transformed into the thermal energy of a gas—it is just the transference of kinetic energy from one body to another.

If we regard potential energy as the kinetic energy of portions of the ether attached to the system, then all energy is kinetic energy, due to the motion of matter or of portions of ether attached to the matter. I showed, many years ago, in my 'Applications of Dynamics to Physics and Chemistry,' that we could imitate the effects of the potential energy of a system by means of the kinetic energy of invisible systems connected in an appropriate manner with the main system, and that the potential energy of the visible universe may in reality be the kinetic energy of an invisible one connected up with it. We naturally suppose that this invisible universe is the luminiferous ether, that portions of the ether in rapid motion are connected with the visible systems, and that their kinetic energy is the potential energy of the systems.

We may thus regard the ether as a bank in which we may deposit energy and withdraw it at our convenience. The mass of the ether attached to the system will change as the potential energy changes, and thus the mass of a system whose potential energy is changing cannot be constant; the fluctuations in mass under ordinary conditions are, however, so small that they cannot be detected by any means at present at our disposal. Inasmuch as the various forms of potential energy are continually being changed into heat energy, which is the kinetic energy of the molecules of matter, there is a constant tendency for the mass of a system such as the earth or the sun to diminish, and thus as time goes on for the mass of ether gripped by the material universe to become smaller and smaller; the rate at which it would diminish would, however, get slower as time went on, and there is no reason to think that it would ever get below a very large value.

Radiation of light and heat from an incandescent body like the sun involves a constant loss of mass by the body. Each unit of energy radiated carries off its quota of mass, but as the mass ejected from the sun per year is only one part in 20 billionths (1 in 2×10^{13}) of the mass of the sun, and as this diminution in mass is not necessarily accompanied by any decrease in its gravitational attraction, we cannot expect to be able to get any evidence of this effect.

As our knowledge of the properties of light has progressed, we have been driven to recognise that the ether, when transmitting light, possesses properties which, before the introduction of the electromagnetic theory, would have been thought to be peculiar to an emission

theory of light and to be fatal to the theory that light consists of undulations.

Take, for example, the pressure exerted by light. This would follow as a matter of course if we supposed light to be small particles moving with great velocities, for these, if they struck against a body, would manifestly tend to push it forward, while on the undulatory theory there seemed no reason why any effect of this kind should take place.

Indeed, in 1792 this very point was regarded as a test between the theories, and Bennet made experiments to see whether or not he could find any traces of this pressure. We now know that the pressure is there, and if Bennet's instrument had been more sensitive he must have observed it. It is perhaps fortunate that Bennet had not at his command more delicate apparatus. Had he discovered the pressure of light, it would have shaken confidence in the undulatory theory and checked that magnificent work at the beginning of the last century which so greatly increased our knowledge of optics.

As another example, take the question of the distribution of energy in a wave of light. On the emission theory the energy in the light is the kinetic energy of the light particles. Thus the energy of light is made up of distinct units, the unit being the energy of one of the particles.

The idea that the energy has a structure of this kind has lately received a good deal of support. Planck, in a very remarkable series of investigations on the Thermodynamics of Radiation, pointed out that the expressions for the energy and entropy of radiant energy were of such a form as to suggest that the energy of radiation, like that of a gas on the molecular theory, was made up of distinct units, the magnitude of the unit depending on the colour of the light; and on this assumption he was able to calculate the value of the unit, and from this deduce incidentally the value of Avogadro's constant—the number of molecules in a cubic centimetre of gas at standard temperature and pressure.

This result is most interesting and important because if it were a legitimate deduction from the Second Law of Thermodynamics, it would appear that only a particular type of mechanism for the vibrators which give out light and the absorbers which absorb it could be in accordance with that law.

If this were so, then, regarding the universe as a collection of machines all obeying the laws of dynamics, the Second Law of Thermodynamics would only be true for a particular kind of machine.

There seems, however, grave objection to this view, which I may illustrate by the case of the First Law of Thermodynamics, the principle of the Conservation of Energy. This must be true whatever be the nature of the machines which make up the universe; provided they obey the laws of dynamics, any application of the principle of the Conservation of Energy could not discriminate between one type of machine and another.

Now, the Second Law of Thermodynamics, though not a dynamical

principle in as strict a sense as the law of the Conservation of Energy, is one that we should expect to hold for a collection of a large number of machines of any type, provided that we could not directly affect the individual machines, but could only observe the average effects produced by an enormous number of them. On this view the Second Law, as well as the First, should be incapable of saying that the machines were of any particular type: so that investigations founded on thermodynamics, though the expressions they lead to may suggest—cannot, I think, be regarded as proving—the unit structure of light energy.

It would seem as if in the application of thermodynamics to radiation some additional assumption has been implicitly introduced, for these applications lead to definite relations between the energy of the light of any particular wave length and the temperature of the luminous body.

Now a possible way of accounting for the light emitted by hot bodies is to suppose that it arises from the collisions of corpuscles with the molecules of the hot body, but it is only for one particular law of force between the corpuscles and the molecules that the distribution of energy would be the same as that deduced by the Second Law of Thermodynamics, so that in this case, as in the other, the results obtained by the application of thermodynamics to radiation would require us to suppose that the Second Law of Thermodynamics is only true for radiation when the radiation is produced by mechanism of a special type.

Quite apart, however, from considerations of thermodynamics, we should expect that the light from a luminous source should in many cases consist of parcels possessing, at any rate to begin with, a definite amount of energy. Consider, for example, the case of a gas like sodium vapour, emitting light of a definite wave length; we may imagine that this light, consisting of electrical waves, is emitted by systems resembling Leyden jars. The energy originally possessed by such a system will be the electrostatic energy of the charged jar. When the vibrations are started, this energy will be radiated away into space, the radiation forming a complex system, containing, if the jar has no electrical resistance, the energy stored up in the jar.

The amount of this energy will depend on the size of the jar and the quantity of electricity with which it is charged. With regard to the charge, we must remember that we are dealing with systems formed out of single molecules, so that the charge will only consist of one or two natural units of electricity, or, at all events, some small multiple of that unit, while for geometrically similar Leyden jars the energy for a given charge will be proportional to the frequency of the vibration; thus, the energy in the bundle of radiation will be proportional to the frequency of the vibration.

We may picture to ourselves the radiation as consisting of the lines of electric force which, before the vibrations were started, were held bound by the charges on the jar, and which, when the vibrations begin,

are thrown into rhythmic undulations, liberated from the jar, and travel through space with the velocity of light.

Now let us suppose that this system strikes against an uncharged condenser and gives it a charge of electricity, the charge on the plates of the condenser must be at least one unit of electricity, because fractions of this charge do not exist, and each unit charge will anchor a unit tube of force, which must come from the parcel of radiation falling upon it. Thus a tube in the incident light will be anchored by the condenser, and the parcel formed by this tube will be anchored and withdrawn as a whole from the pencil of light incident on the condenser. If the energy required to charge up the condenser with a unit of electricity is greater than the energy in the incident parcel, the tube will not be anchored and the light will pass over the condenser and escape from it. These principles, that radiation is made up of units, and that it requires a unit possessing a definite amount of energy to excite radiation in a body on which it falls, perhaps receive their best illustration in the remarkable laws governing Secondary Röntgen radiation, recently discovered by Professor Barkla. Professor Barkla has found that each of the different chemical elements, when exposed to Röntgen rays, emit a definite type of secondary radiation whatever may have been the type of primary: thus lead emits one type, copper another, and so on; but these radiations are not excited at all if the primary radiation is of a softer type than the specific radiation emitted by the substance; thus the secondary radiation from lead being harder than that from copper, if copper is exposed to the secondary radiation from lead the copper will radiate, but lead will not radiate when exposed to copper. Thus, if we suppose that the energy in a unit of hard Röntgen rays is greater than that in one of soft, Barkla's results are strikingly analogous to those which would follow on the unit theory of light.

Though we have, I think, strong reasons for thinking that the energy in the light waves of definite wave length is done up into bundles, and that these bundles, when emitted, all possess the same amount of energy, I do not think there is any reason for supposing that in any casual specimen of light of this wave length, which may subsequent to its emission have been many times refracted or reflected, the bundles possess any definite amount of energy. For consider what must happen when a bundle is incident on a surface such as glass, when part of it is reflected and part transmitted. The bundle is divided into two portions, in each of which the energy is less than the incident bundle, and since these portions diverge and may ultimately be many thousands of miles apart, it would seem meaningless still to regard them as forming one unit. Thus the energy in the bundles of light, after they have suffered partial reflection, will not be the same as in the bundles when they were emitted. The study of the dimensions of these bundles, for example, the angle they subtend at the luminous source, is an interesting

subject for investigation; experiments on interference between rays of light emerging in different directions from the luminous source would probably throw light on this point.

I now pass to a very brief consideration of one of the most important and interesting advances ever made in physics, and in which Canada, as the place of the labours of Professors Rutherford and Soddy, has taken a conspicuous part. I mean the discovery and investigation of radio-activity. Radio-activity was brought to light by the Röntgen rays. One of the many remarkable properties of these rays is to excite phosphorescence in certain substances, including the salts of uranium, when they fall upon them. Since Röntgen rays produce phosphorescence, it occurred to Becquerel to try whether phosphorescence would produce Röntgen rays. He took some uranium salts which had been made to phosphoresce by exposure, not to Röntgen rays but to sunlight, tested them, and found that they gave out rays possessing properties similar to Röntgen rays. Further investigation showed, however, that to get these rays it was not necessary to make the uranium phosphoresce, that the salts were just as active if they had been kept in the dark. It thus appeared that the property was due to the metal and not to the phosphorescence, and that uranium and its compounds possessed the power of giving out rays which, like Röntgen rays, affect a photographic plate, make certain minerals phosphoresce, and make gases through which they pass conductors of electricity.

Niepce de Saint-Victor had observed some years before this discovery that paper soaked in a solution of uranium nitrate affected a photographic plate, but the observation excited but little interest. The ground had not then been prepared, by the discovery of the Röntgen rays, for its reception, and it withered and was soon forgotten.

Shortly after Becquerel's discovery of uranium, Schmidt found that thorium possessed similar properties. Then Monsieur and Madame Curie, after a most difficult and laborious investigation, discovered two new substances, radium and polonium, possessing this property to an enormously greater extent than either thorium or uranium, and this was followed by the discovery of actinium by Debierne. Now the researches of Rutherford and others have led to the discovery of so many new radio-active substances that any attempts at christening seems to have been abandoned, and they are denoted, like policemen, by the letters of the alphabet.

Mr. Campbell has recently found that potassium, though far inferior in this respect to any of the substances I have named, emits an appreciable amount of radiation, the amount depending only on the quantity of potassium, and being the same whatever the source from which the potassium is obtained or whatever the elements with which it may be in combination.

The radiation emitted by these substances is of three types, known

as α, β, and γ rays. The α rays have been shown by Rutherford to be positively electrified atoms of helium, moving with speeds which reach up to about one-tenth of the velocity of light. The β rays are negatively electrified corpuscles, moving in some cases with very nearly the velocity of light itself, while the γ rays are unelectrified, and are analogous to the Röntgen rays.

The radio-activity of uranium was shown by Crookes to arise from something mixed with the uranium, and which differed sufficiently in properties from the uranium itself to enable it to be separated by chemical analysis. He took some uranium, and by chemical treatment separated it into two portions, one of which was radio-active and the other not.

Next Becquerel found that if these two portions were kept for several months, the part which was not radio-active to begin with gained radio-activity, while the part which was radio-active to begin with had lost its radio-activity. These effects and many others receive a complete explanation by the theory of radio-active change which we owe to Rutherford and Soddy.

According to this theory, the radio-active elements are not permanent, but are gradually breaking up into elements of lower atomic weight; uranium, for example, is slowly breaking up, one of the products being radium, while radium breaks up into a radio-active gas called radium emanation, the emanation into another radio-active substance, and so on, and that the radiations are a kind of swan's song emitted by the atoms when they pass from one form to another; that, for example, it is when a radium atom breaks up and an atom of the emanation appears that the rays which constitute the radio-activity are produced.

Thus, on this view the atoms of the radio-active elements are not immortal: they perish after a life whose average value ranges from thousands of millions of years in the case of uranium to a second or so in the case of the gaseous emanation from actinium.

When the atoms pass from one state to another they give out large stores of energy, thus their descendants do not inherit the whole of their wealth of stored-up energy, the estate becomes less and less wealthy with each generation; we find, in fact, that the politician when he imposes death duties is but imitating a process which has been going on for ages in the case of these radio-active substances.

Many points of interest arise when we consider the rate at which the atoms of radio-active substance disappear. Rutherford has shown that whatever be the age of these atoms, the percentage of atoms which disappear in one second is always the same; another way of putting it is that the expectation of life of an atom is independent of its age—that an atom of radium a thousand years old is just as likely to live for another thousand years as one just sprung into existence.

Now this would be the case if the death of the atom were due to

something from outside which struck old and young indiscriminately; in a battle, for example, the chance of being shot is the same for old and young; so that we are inclined at first to look to something coming from outside as the cause why an atom of radium, for example, suddenly changes into an atom of the emanation. But here we are met with the difficulty that no changes in the external conditions that we have as yet been able to produce have had any effect on the life of the atom; as far as we know at present the life of a radium atom is the same at the temperature of a furnace as at that of liquid air—it is not altered by surrounding the radium by thick screens of lead or other dense materials to ward off radiation from outside, and, what to my mind is especially significant, it is the same when the radium is in the most concentrated form, when its atoms are exposed to the vigorous bombardment from the rays given off by the neighbouring atoms, as when it is in the most dilute solution, when the rays are absorbed by the water which separates one atom from another. This last result seems to me to make it somewhat improbable that we shall be able to split up the atoms of the non-radio-active elements by exposing them to the radiation from radium; if this radiation is unable to affect the unstable radio-active atoms, it is somewhat unlikely that it will be able to affect the much more stable non-radio-active elements.

The evidence we have at present is against a disturbance coming from outside breaking up of the radio-active atoms, and we must therefore look to some process of decay in the atom itself; but if this is the case, how are we to reconcile it with the fact that the expectation of life of an atom does not diminish as the atom gets older? We can do this if we suppose that the atoms when they are first produced have not all the same strength of constitution, that some are more robust than others, perhaps because they contain more intrinsic energy to begin with, and will therefore have a longer life. Now if when the atoms are first produced there are some which will live for one year, some for ten, some for a thousand, and so on; and if lives of all durations, from nothing to infinity, are present in such proportion that the number of atoms which will live longer than a certain number of years decrease in a constant proportion for each additional year of life, we can easily prove that the expectation of life of an atom will be the same whatever its age may be. On this view the different atoms of a radio-active substance are not, in all respects, identical.

The energy developed by radio-active substances is exceedingly large, one gramme of radium developing nearly as much energy as would be produced by burning a ton of coal. This energy is mainly in the α particles, the positively charged helium atoms which are emitted when the change in the atom takes place; if this energy were produced by electrical forces it would indicate that the helium atom had moved through a potential difference of about two million volts on its way out of the atom of

radium. The source of this energy is a problem of the deepest interest; if it arises from the repulsion of similarly electrified systems exerting forces varying inversely as the square of the distance, then to get the requisite amount of energy the systems, if their charges were comparable with the charge on the α particle, could not when they start be further apart than the radius of a corpuscle, 10^{-13} cm. If we suppose that the particles do not acquire this energy at the explosion, but that before they are shot out of the radium atom they move in circles inside this atom with the speed with which they emerge, the forces required to prevent particles moving with this velocity from flying off at a tangent are so great that finite charges of electricity could only produce them at distances comparable with the radius of a corpuscle.

One method by which the requisite amount of energy could be obtained is suggested by the view to which I have already alluded—that in the atom we have electrified systems of very different types, one small, the other large; the radius of one type is comparable with 10^{-13} cm., that of the other is about 100,000 times greater. The electrostatic potential energy in the smaller bodies is enormously greater than that in the larger ones; if one of these small bodies were to explode and expand to the size of the larger ones, we should have a liberation of energy large enough to endow an α particle with the energy it possesses. Is it possible that the positive units of electricity were, to begin with, quite as small as the negative, but while in the course of ages most of these have passed from the smaller stage to the larger, there are some small ones still lingering in radio-active substances, and it is the explosion of these which liberates the energy set free during radio-active transformation?

The properties of radium have consequences of enormous importance to the geologist as well as to the physicist or chemist. In fact, the discovery of these properties has entirely altered the aspect of one of the most interesting geological problems, that of the age of the earth. Before the discovery of radium it was supposed that the supplies of heat furnished by chemical changes going on in the earth were quite insignificant, and that there was nothing to replace the heat which flows from the hot interior of the earth to the colder crust. Now when the earth first solidified it only possessed a certain amount of capital in the form of heat, and if it is continually spending this capital and not gaining any fresh heat it is evident that the process cannot have been going on for more than a certain number of years, otherwise the earth would be colder than it is. Lord Kelvin in this way estimated the age of the earth to be less than 100 million years. Though the quantity of radium in the earth is an exceedingly small fraction of the mass of the earth, only amounting according to the determinations of Professors Strutt and Joly to about five grammes in a cube whose side is 100 miles, yet the amount of heat given out by this small quantity of radium is so great that it is more than enough to replace the heat which flows from the

inside to the outside of the earth. This, as Rutherford has pointed out, entirely vitiates the previous method of determining the age of the earth. The fact is that the radium gives out so much heat that we do not quite know what to do with it, for if there was as much radium throughout the interior of the earth as there is in its crust, the temperature of the earth would increase much more rapidly than it does as we descend below the earth's surface. Professor Strutt has shown that if radium behaves in the interior of the earth as it does at the surface, rocks similar to those in the earth's crust cannot extend to a depth of more than forty-five miles below the surface.

It is remarkable that Professor Milne from the study of earthquake phenomena had previously come to the conclusion that rocks similar to those at the earth's surface only descend a short distance below the surface; he estimates this distance at about thirty miles, and concludes that at a depth greater than this the earth is fairly homogeneous.

Though the discovery of radio-activity has taken away one method of calculating the age of the earth, it has supplied another.

The gas helium is given out by radio-active bodies, and since, except in beryls, it is not found in minerals which do not contain radio-active elements, it is probable that all the helium in these minerals has come from these elements. In the case of a mineral containing uranium, the parent of radium in radio-active equilibrium, with radium and its products, helium will be produced at a definite rate. Helium, however, unlike the radio-active elements, is permanent and accumulates in the mineral; hence if we measure the amount of helium in a sample of rock and the amount produced by the sample in one year we can find the length of time the helium has been accumulating, and hence the age of the rock. This method, which is due to Professor Strutt, may lead to determinations not merely of the average age of the crust of the earth but of the ages of particular rocks and the date at which the various strata were deposited; he has, for example, shown in this way that a specimen of the mineral thorianite must be more than 240 million years old.

The physiological and medical properties of the rays emitted by radium is a field of research in which enough has already been done to justify the hope that it may lead to considerable alleviation of human suffering. It seems quite definitely established that for some diseases, notably rodent ulcer, treatment with these rays has produced remarkable cures; it is imperative, lest we should be passing over a means of saving life and health, that the subject should be investigated in a much more systematic and extensive manner than there has yet been either time or material for. Radium is, however, so costly that few hospitals could afford to undertake pioneering work of this kind; fortunately, however, through the generosity of Sir Ernest Cassel and Lord Iveagh a Radium Institute, under the patronage of his Majesty the King, has been founded in London for the study of the medical properties of radium, and for the

treatment of patients suffering from diseases for which radium is beneficial.

The new discoveries made in physics in the last few years, and the ideas and potentialities suggested by them, have had an effect upon the workers in that subject akin to that produced in literature by the Renaissance. Enthusiasm has been quickened, and there is a hopeful, youthful, perhaps exuberant, spirit abroad which leads men to make with confidence experiments which would have been thought fantastic twenty years ago. It has quite dispelled the pessimistic feeling, not uncommon at that time, that all the interesting things had been discovered, and all that was left was to alter a decimal or two in some physical constant. There never was any justification for this feeling, there never were any signs of an approach to finality in science. The sum of knowledge is at present, at any rate, a diverging not a converging series. As we conquer peak after peak we see in front of us regions full of interest and beauty, but we do not see our goal, we do not see the horizon; in the distance tower still higher peaks, which will yield to those who ascend them still wider prospects, and deepen the feeling, whose truth is emphasised by every advance in science, that 'Great are the Works of the Lord.'

REPORTS

ON THE

STATE OF SCIENCE.

REPORTS

ON THE

STATE OF SCIENCE.

The Further Tabulation of Bessel Functions.—Report of the Committee, consisting of Professor M. J. M. Hill (*Chairman*), Dr. L. N. G. Filon (*Secretary*), Professor Alfred Lodge, *and* Dr. J. W. Nicholson.

The Committee have made further progress with the calculations. Using the notation of previous Reports, values of $Q_n(x)$ have been calculated for integral values of n, from $n=1$ to $n=6$. These are shown in Table IV. below, together with the values for $n=0$, which are reprinted from Table III. of the Report of the Committee for 1907.

From these the values of α $(=\sin^{-1}(Q/R))$ have been computed from $n=0$ to $n=6$. To these are added the values for $n=\frac{1}{2}$, $1\frac{1}{2}$, . . . $6\frac{1}{2}$, for which the semi-convergent expansions for the Bessel function terminate, which renders the computation easier.

Instead of α itself, however, $\log\{8x\alpha/(4n^2-1)\}$ has been tabulated in Table V. below. The reason is that this quantity is fairly adapted for interpolation both for intermediate values of x and for intermediate values of n, as it varies comparatively slowly, especially for large values of x. For values of x greater than 1,000 (which is the largest argument in the table) $\log\{8x\alpha/(4n^2-1)\}$ is very sensibly zero: in no such case does it differ from zero by more than about 1 in the sixth place of decimals.

From $\log\{8x\alpha/(4n^2-1)\}$, $\log\alpha$ and hence α are readily calculated. $J_n(x)$ is then found from the formula

$$\log J_n(x)=\log\left\{R\sqrt{\frac{2}{\pi}}\right\}-\tfrac{1}{2}\log x+\log\cos\left(x+\alpha-\frac{\pi}{4}-n\frac{\pi}{2}\right),$$

the values of $\log\left\{R\sqrt{\frac{2}{\pi}}\right\}$ being taken from Table II. of the 1907 Report.

From the tables of the present Report and those of the 1907 Report the values of $J_n(x)$ for values of n ranging from $n=0$ to $n=6\frac{1}{2}$ at intervals

APPENDIX TO REPORT ON BESSEL FUNCTIONS.

TABLE IV.[1]

[Last figure approximate.]

x	$Q_0(x)$	$Q_1(x)$	$Q_2(x)$	$Q_3(x)$	$Q_4(x)$	$Q_5(x)$	$Q_6(x)$
10	−·012 428 881	.037 400 059	·187 802 740	·434 131 080	·743 424 930	1·019 210 213	1·074 721 955
20	−·006 240 9144	·018 737 2678	·093 788 2934	·218 327 505	·388 248 619	·591 308 678	·801 366 105
30	−·004 163 9632	·012 496 2136	·062 511 3721	·145 708 071	·260 870 409	·404 360 689	·568 280 322
40	−·003 123 8578	·009 373 4005	·046 879 8015	·109 322 143	·196 203 419	·305 939 965	·435 224 505
50	−·002 499 4148	·007 499 1806	·037 502 4593	·087 472 9346	·157 148 058	·245 740 962	·351 528 651
60	−·002 082 9945	·006 249 5257	·031 251 4235	·072 901 0030	·131 046 335	·205 231 944	·294 459 046
70	−·001 785 5309	·005 356 8442	·026 786 6108	·062 490 1356	·112 371 746	·176 144 571	·253 178 998
80	−·001 562 3571	·004 687 2998	·023 438 1006	·054 680 8916	·098 351 5808	·154 257 968	·221 977 986
90	−·001 388 7884	·004 166 5260	·020 833 7552	·048 606 4697	·087 439 6566	·137 198 319	·197 585 891
100	−·001 249 9268	·003 749 8975	·018 750 3075	·043 746 6164	·078 706 0098	·123 530 070	·178 002 532
200	−·000 624 9908	·001 874 9872	·009 375 0385	·021 874 5770	·039 369 5013	·061 847 5072	·089 281 5337
300	−·000 416 6640	·001 249 9962	·006 250 0114	·014 583 2080	·026 248 3708	·041 241 8539	·059 555 6378
400	−·000 312 4989	·000 937 4984	·004 687 5048	·010 937 4471	·019 686 8285	·030 934 0633	·044 675 8157
500	−·000 249 9994	·000 749 9992	·003 750 0025	·008 749 9729	·015 749 6481	·024 748 2404	·035 744 0176
600	−·000 208 3330	·000 624 9995	·003 125 0014	·007 291 6510	·013 124 7963	·020 623 9817	·029 788 2046
700	−·000 178 5712	·000 535 7140	·002 678 5723	·006 249 9901	·011 249 8718	·017 677 9302	·025 533 5341
800	−·000 156 2499	·000 468 7498	·002 343 7506	·005 468 7434	·009 843 6641	·015 468 3204	·022 342 2894
900	−·000 138 8888	·000 416 6666	·002 083 3337	·004 861 1065	·008 749 9397	·013 749 6983	·019 860 0853
1000	−·000 124 9999	·000 374 9999	·001 875 0003	·004 374 9966	·007 874 9560	·012 374 7801	·017 874 2522

[1] For Tables I., II., and III., see *Brit. Assoc. Report*, 1906.

TABLE V.

Values of $\log \frac{8xa}{4n^2-1}$. [*Last figure approximate.*]

x	$n=0$ $\log(-8xa)$	$n=\frac{1}{2}$	$n=1$ $\log\left(\frac{8xa}{3}\right)$	$n=1\frac{1}{2}$ $\log xa$	$n=2$ $\log\frac{8xa}{15}$	$n=2\frac{1}{2}$ $\log\frac{xa}{3}$	$n=3$ $\log\frac{8xa}{35}$	$n=3\frac{1}{2}$ $\log\frac{xa}{6}$	$n=4$ $\log\frac{8xa}{63}$	$n=4\frac{1}{2}$ $\log\frac{xa}{10}$	$n=5$ $\log\frac{8xa}{99}$	$n=5\frac{1}{2}$ $\log\frac{xa}{15}$	$n=6$ $\log\frac{8xa}{143}$	$n=6\frac{1}{2}$ $\log\frac{xa}{21}$
10	$\bar{1}$·997 8005	$\bar{1}$·997 8842	$\bar{1}$·998 1364	$\bar{1}$·998 5586	$\bar{1}$·999 1531	$\bar{1}$·999 9235	0·000 8746	0·002 0122	0·003 3437	0·004 8773	0·006 5733	0·008 5931	0·010 7983	0·013 2539
20	999 4387	999 4608	$\bar{1}$·999 5275	$\bar{1}$·999 6385	999 7909	9952	2414	000 5334	000 8720	001 2575	001 6565	002 1723	002 7038	003 2856
30	7495	7594	7894	8392	9091	9990	1092	2394	3901	000 5612	000 7531	000 9655	001 1992	001 4537
40	8589	8645	8905	9124	9490	9997	0617	1351	2199	3161	4238	5430	000 6766	000 8162
50	9096	9132	9239	9419	9674	9999	0396	0866	1409	2024	2713	3475	4310	5220
60	9372	9401	9473	9598	9774	nil	0275	0602	0979	1406	1884	2413	2992	3623
70	9539	9556	9610	9704	9834	—	0203	0443	0719	1033	1385	1773	2198	2661
80	9647	9661	9702	9773	9873	—	0155	0339	0551	0791	1060	1357	1683	2037
90	9721	9732	9765	9821	9900	—	0123	0268	0436	0625	0838	1072	1330	1609
100	9774	9789	9810	9855	9918	—	0100	0217	0353	0507	0679	0869	1077	1303
200	943	946	953	962	980	—	025	054	088	127	170	217	269	326
300	975	976	979	984	991	—	011	024	039	056	075	097	120	145
400	986	986	989	991	995	—	006	014	022	032	042	054	067	081
500	991	991	993	995	997	—	004	009	014	020	027	035	043	052
600	994	994	996	996	998	—	003	006	010	014	019	024	030	036
700	995	996	997	997	998	—	002	004	007	010	014	018	022	027
800	996	997	998	998	999	—	002	003	006	008	011	014	017	020
900	997	998	998	998	999	—	001	003	004	006	008	011	013	016
1000	998	999	999	999	999	nil	001	002	004	005	007	009	011	013
Values of a	$\frac{1}{10}\cot^{-1}\frac{4x}{5}$ (approx.)	$a=0$	...	$a=\cot^{-1}x$	...	$\cot^{-1}\left(\frac{x}{3}-\frac{1}{x}\right)$								

$J_n(x)=\sqrt{\frac{2}{\pi x}}\,.\,R\cos\left(x+a-\frac{\pi}{4}-n\frac{\pi}{2}\right)$, where $R\sqrt{\frac{2}{\pi x}}$ is the amplitude, and $\cos\left(x+a-\frac{\pi}{4}-n\frac{\pi}{2}\right)$ is the oscillating factor.

Values of $\log\left\{R\sqrt{\frac{2}{\pi}}\right\}$ are given in Table II. of the Report for 1907. To obtain the amplitude, subtract $\frac{1}{2}\log x$.

Values of a can be obtained from the above table.

Both these tables are arranged for approximate interpolation for both x and n, for which they are suitable when x is large.

Approximate values of a can also be obtained directly from the series for a when x is large,

viz.: $a=\frac{k}{x}+\frac{k(k-3)}{6x^3}+\frac{k(k^2-14k+15)}{10x^5}+$ &c., where $k=\frac{1}{8}(4n^2-1)$.

of $\frac{1}{2}$, and for values of x greater than 10, can be computed to six places without sensible error.

It is to be noted that the Neumann function $Y_n(x)$ can be calculated from the same data, for

$$\log\{Y_n(x)-(\log_e 2-\gamma)\,J_n(x)\}$$
$$=\log\left\{R\sqrt{\frac{2}{\pi}}\right\}-\tfrac{1}{2}\log x+\log\sin\left(x+a-\frac{\pi}{4}-n\frac{\pi}{2}\right),$$

γ being Euler's constant. [$\log_e 2-\gamma=0{\cdot}1159315\ldots$]

The Committee are at present engaged on the tabulation of $K_n(x)$, and hope to make some additions to the British Association Tables of $I_n(x)$ which are to be found in the Reports for 1889, 1893, and 1896. They are also considering the advisability of collecting all existing tables of Bessel functions and publishing them as a single set of tables in a form easily accessible to all students.

The Committee desire reappointment without a grant.

Magnetic Observations at Falmouth Observatory.—Report of the Committee, consisting of Sir W. H. PREECE (*Chairman*), Dr. R. T. GLAZEBROOK (*Secretary*), Professor W. G. ADAMS, Dr. CHREE, Captain CREAK, Mr. W. L. FOX, Sir ARTHUR RÜCKER, *and* Professor SCHUSTER.

THE results of the magnetic observations at Falmouth Observatory for 1908 have been published in the Annual Report of the National Physical Laboratory as well as in that of the Royal Cornwall Polytechnic Society. The mean values of the magnetic elements for 1908 were:—

Declination	17° 54′·7 W.
Inclination	66° 31′·4 N.
Horizontal Force	0·18798 C.G.S.
Vertical Force	0·43279 C.G.S.

The accuracy of the work seems to be satisfactorily maintained.

Throughout the year Mr. Kitto has been regularly contributing particulars of the daily magnetic condition as regards disturbance to the international tables which are at present prepared at de Bilt, Holland.

Dr. Chree has recently been engaged on a comparison of the magnetic disturbances recorded at the winter quarters of the National Antarctic Expedition of 1902-4 with those recorded simultaneously elsewhere, and has found the Falmouth curves very useful for this purpose. It is found that for purposes of intercomparison, disturbances of comparatively small size when of short duration are in many respects simpler to deal with than the larger disturbances during which rapid oscillatory movements take place. But in handling the smaller disturbances, and in settling the exact times of their occurrence, it is of special importance to have curves whose edges are sharp and which are not blurred and indistinct through the disturbing effect of electric trams. Thus the undisturbed position of Falmouth proved of very material assistance.

The comparison of magnetic disturbances is a subject to which increased attention is being given, as evidenced, for instance, by Prof. Birkeland's recent important work on the subject.

The Committee learn that the progress of the magnetic work at Eskdalemuir has been further delayed owing to troubles with the underground chamber and the magnetographs, so that no opportunity has yet arisen for comparing the regular diurnal inequalities of the magnetic elements obtained at that station with those obtained in the South of England. For such a comparison records from Falmouth are likely to be of especial importance. Believing that the continued maintenance of magnetic work at Falmouth in full efficiency is highly desirable, the Committee ask for reappointment with a grant of 50*l*.

Geodetic Arc in Africa.—Report of the Committee, consisting of Sir GEORGE DARWIN (*Chairman*), Sir DAVID GILL (*Secretary*), Colonel C. F. CLOSE, *and* Sir GEORGE GOLDIE, *appointed to carry out a further portion of the Geodetic Arc of Meridian North of Lake Tanganyika.*

1. The measurement was commenced in March 1908 and completed in February 1909. The arc extends from 1° 10′ N. to 1° 10′ S., *i.e.*, the length is 2⅓ degrees, or about 165 miles.

2. One base, length eleven miles, was measured in the northern portion, in the Semliki Valley. The chain consists of one complex figure, three quadrilaterals, and one tetragon.

3. All the stations have been marked in a permanent manner, and the Government of Uganda has been notified of their positions.

4. The probable error of an observed angle is about 0.4″.

5. Three azimuths and fourteen latitudes were observed.

6. Magnetic observations for declination and dip were made at twenty stations.

7. The work was organised by Major Bright, C.M.G., and carried out by a British party consisting of Captain Jack, R.E., Mr. McCaw, Mr. C. Chevallier, Lance-Corporal Jones, R.E., Lance-Corporal Page, R.E., and for a portion of the time Captain S. Iredell, 4th Battalion King's African Rifles, who also commanded the escort.

The Belgian party consisted of Captain Wangermée and Dr. Dehalu.

Investigation of the Upper Atmosphere by means of Kites in co-operation with a Committee of the Royal Meteorological Society.—Eighth Report of the Committee, consisting of Dr. W. N. SHAW (*Chairman*), Mr. W. H. DINES (*Secretary*), Mr. D. ARCHIBALD, Mr. C. VERNON BOYS, Dr. R. T. GLAZEBROOK, Dr. H. R. MILL, Professor J. E. PETAVEL, Professor A. SCHUSTER, *and* Dr. W. WATSON. (*Drawn up by the Secretary*).

A MEETING was held in the rooms of the Royal Meteorological Society in November, at which it was decided that observations with pilot balloons should be made in Barbados, and Mr. Cave, who stated that he was going to Barbados, was asked to make the necessary arrangements, which he agreed to do.

Mr. Cave was prevented from going as he had intended, and in consequence the observations were not inaugurated, but the necessary

instruments have been obtained, and it is hoped that the observations will be made at some future date.

The grant of 10*l.* made at Dublin has been allotted to Professor Petavel to aid in meeting the expenses of a special inquiry as to the daily variation of temperature at great heights. Professor Petavel arranged for sending up twenty-five registering balloons at Manchester on June 2-3, 1909, at hourly intervals; and a very fair number of the balloons, well distributed over the twenty-four hours, have been found. It is hoped that when the traces have been worked up some interesting information will be available.

Experiments for Improving the Construction of Practical Standards for Electrical Measurements.—Report of the Committee, consisting of Lord RAYLEIGH (*Chairman*), Dr. R. T. GLAZEBROOK (*Secretary*), Professors J. PERRY, W. G. ADAMS, *and* G. CAREY FOSTER, Sir OLIVER LODGE, Dr. A. MUIRHEAD, Sir W. H. PREECE, Professors A. SCHUSTER, J. A. FLEMING, *and* Sir J. J. THOMSON, Dr. W. N. SHAW, Dr. J. T. BOTTOMLEY, Rev. T. C. FITZPATRICK, Dr. G. JOHNSTONE STONEY, Professor S. P. THOMPSON, Mr. J. RENNIE, Principal E. H. GRIFFITHS, Sir ARTHUR RÜCKER, Professor H. L. CALLENDAR, and Messrs. G. MATTHEY, A. P. TROTTER, T. MATHER, *and* F. E. SMITH.

THE Committee desire in the first place to record their sense of the great loss electrical science has sustained since their last meeting by the death of Professor Ayrton, F.R.S. The revival of the Electrical Standards Committee was proposed by him at the Swansea Meeting in 1880. He had been a member since that date, and much of the work of the Committee owes its initiation to his inspiration. He contributed greatly to the success of the Ayrton-Jones ampere balance, and was deeply interested in the preparations for the Lorenz apparatus now being erected at the National Physical Laboratory as the gift of the Drapers' Company in memory of Professor Viriamu Jones. The Committee will miss in no small degree his keen criticism and his active help.

The International Conference on Electrical Units and Standards, referred to in previous Reports, met, on the invitation of H.M. Government, in the rooms of the Royal Society, from October 12 to October 22, 1908. It was attended by forty-six delegates, representing twenty-two countries and four British dependencies. The Report of the Conference is printed as an Appendix to this Report. In accordance with one of the resolutions passed by the Conference, Lord Rayleigh, as Chairman, appointed a committee of fifteen to advise as to the organisation of a permanent Commission, to formulate a plan for and to direct such work as may be necessary in connection with the maintenance of standards, fixing of values and intercomparisons of standards, and to complete the work of the Conference.

The work of this Committee is now in progress, and it is proposed that representatives of the National Physical Laboratory and of the Reichsanstalt should visit Washington this autumn.

In their last Report the Committee suggested the republication of the Reports of the original Committee from 1862 to 1871, and of the present Committee from 1881, as a memorial to the connection of Lord Kelvin with their work. They are glad to learn that the recommendation from the Committee of Section A in favour of this course has been accepted by the Council, and that a proposal to undertake the projected republication will be made to the General Committee at Winnipeg.

The Committee are greatly indebted to Mr. R. K. Gray for a generous donation of 100*l.* towards the expenses of this work.

In the Appendix to the Report of the Committee for 1905 it is stated that slight variations in the electromotive force of the Weston normal cell can be produced by 12½ per cent. cadmium amalgam. A preliminary investigation showed that the variations were generally very small and not easily reproduced. In general the electromotive force was normal at 0° C. A more exhaustive investigation has now been completed at the National Physical Laboratory, and the results show that in general the 12½ per cent. amalgam may be used from 0° C. to above 60° without any appreciable error, but the E.M.F. of a standard cell containing such an amalgam *may be* very normal at all temperatures below 12° C. The limits of temperature for the general use of a 12½ per cent. amalgam are very nearly 12° C. to 62° C. A 10 per cent. amalgam may be used between 0° C. and 51° C.

Progress with the Lorenz apparatus has been slow but satisfactory. The difficulties attending the driving have been overcome to a considerable extent: an electric motor will be installed. The iron of the motor has been demonstrated to have no appreciable effect on the mutual induction of the Lorenz system when a small addition to the electrical system is introduced.

A comparison between the standards of resistance used at the National Physical Laboratory, the National Bureau of Standards, and the Physikalisch-Technische Reichsanstalt has been made by the use of some hermetically sealed standards belonging to the Bureau of Standards. The following tables give the results obtained:—

TABLE I.—*Giving the Results of Comparisons made February-March* 1908. *Values at* 20° C.

No. of Coil	Resistance as determined at			Difference Parts in 100,000	
	N.B.S. (Jan.)	N.P.L. (Feb.)	P.T.R. (Mar.)	N.P.L.– N.B.S.	N.P.L.– P.T.R.
1. (B.S. 1102A) .	$0{\cdot}99980_1$	$0{\cdot}99982_9$	$0{\cdot}99981_6$	2·8	1·3
2. (B.S. 1102B) .	$0{\cdot}99975_0$	$0{\cdot}99977_6$	$0{\cdot}99975_9$	2·6	1·7
3. (B.S. 1102C) .	$1{\cdot}00000_0$	$1{\cdot}00002_2$	$1{\cdot}00001_0$	2·2	1·2
12. (B.S. 2415D) .	$0{\cdot}99998_2$	$0{\cdot}99999_7$	$0{\cdot}99997_5$	1·5	2·2
1. (B.S. 3946E) .	$99{\cdot}990_8$	$99{\cdot}991_5$	$99{\cdot}991_6$	1·2	−0·1
2. (B.S. 3946F) .	$99{\cdot}985_8$	$99{\cdot}987_1$	$99{\cdot}987_2$	1·3	−0·1
1. (B.S. 3946I) .	$999{\cdot}90_2$	$999{\cdot}92_0$	—	1·8	—
2. (B.S. 3946J) .	$1000{\cdot}01_9$	$1000{\cdot}03_5$	—	1 6	—
			Mean .	1·9	1·0

TABLE II.—*Giving the Results of Comparisons made November* 1908 *to March* 1909. *Values at* 20° C.

No. of Coil	Resistance as determined at				Difference Parts in 100,000	
	N.B.S. (Sep. 1908)	N.P.L. (Nov. 1908)	P.T.R. (Nov. 1908 Jan. 1909)	N.P.L. (Feb.–Mar. 1909)	N.P.L.–N.B.S.	N.P.L.–P.T.R.
1. (B.S. 1102A) .	$0{\cdot}99999_7$	$1{\cdot}00002_3$	—	—	2·6	—
2. (B.S. 1102B) .	$0{\cdot}99999_7$	$1{\cdot}00002_2$	—	—	2·5	—
3. (B.S. 1102C) .	$1{\cdot}00000_0$	$1{\cdot}00001_6$	—	—	1·6	—
4. (B.S. 1102D) .	$0{\cdot}99999_1$	$1{\cdot}00001_1$	$0{\cdot}99999_9$	$1{\cdot}00001_8$	2·1	1·6
11. (B.S. 5315C) .	$0{\cdot}99999_1$	$1{\cdot}00001_4$	$1{\cdot}00000_8$	$1{\cdot}00002_3$	2·9	1·2
12. (B.S 5315D) .	$0{\cdot}99998_1$	$1{\cdot}00000_3$	$1{\cdot}99998_9$	$1{\cdot}00001_1$	2·6	1·8
1. (B.S. 3946E) .	$99{\cdot}991_6$	$99{\cdot}994_5$	—	—	2·9	—
2. (B.S. 3946F) .	$99{\cdot}987_5$	$99{\cdot}990_7$	—	—	3·2	—
				Mean .	2·5	1·5

The unit coils Nos. 1 and 2 were adjusted at Washington on September 23, 1908, so as to give values more nearly equal to the nominal. The changes made were $+0{\cdot}00019_6$ ohm and $+0{\cdot}00024$ ohm respectively.

Analysis of all the data relating to the comparisons indicates that the coil No. 11 (Table II.) changed by about 0·00001 ohm during transportation from Teddington to Charlottenburg.

No. 12 is a comparatively new coil, having been sealed in January 1908.

At the Bureau of Standards (Washington) wire coils were employed as standards in all the comparisons.

The values given by the N.P.L. in Table I. are in terms of the N.P.L. mercury standards of resistance, which were set up in November to December 1907. The N.P.L. values in Table II. are in terms of the mercury standards of resistance which were erected in February 1909.

With respect to the values given by the Reichsanstalt, in Table I., Dr. Lindeck states, 'The last complete series of measurements on the standards of the Reichsanstalt was carried out at the end of January and the beginning of February. The values given in the Table (I.) are based upon this series.'

In Table II. the P.T.R. values depend upon the values assigned to a wire standard of the Reichsanstalt which had been kept for about a year in an atmosphere of constant humidity, and frequently compared with other standards of resistance.

In conclusion the Committee recommend that they be reappointed for the purpose of continuing their researches on the standards and carrying out the republications of the Reports if sanctioned by the General Committee, and that Lord Rayleigh be Chairman and Dr. R. T. Glazebrook Secretary.

APPENDIX.

International Conference on Electrical Units and Standards, 1908.

Report.

The Conference on Electrical Units and Standards, for which invitations were issued by the British Government, was opened by the President of the Board of Trade, the Right Hon. Winston S. Churchill, M.P., on Monday, October 12, 1908, at Burlington House, London, W.

Delegates were present from twenty-two countries, and also from the following British Dependencies—namely, Australia, Canada, India, and the Crown Colonies.

It was decided by the Conference that a vote each should be allowed to Australia, Canada, and India, but a vote was not claimed or allowed for the Crown Colonies.

The total number of Delegates to the Conference was forty-six, and their names are set out in Schedule A to this Report.

The officers of the Conference were:—

President.

The Right Hon. Lord Rayleigh, O.M., President of the Royal Society.

Vice-Presidents.

Professor S. A. Arrhenius.	M. Lippmann.
Dr. N. Egoroff.	Dr. S. W. Stratton.
Dr. Viktor Edler von Lang.	Dr. E. Warburg.

Secretaries.

Mr. M. J. Collins.	Mr. C. W. S. Crawley.
Mr. W. Duddell, F.R.S.	Mr. F. E. Smith.

The Conference elected a Technical Committee to draft specifications and to consider any matter which might be referred to the Committee and to report to the Conference.

The Conference and its Technical Committee each held five sittings.

As a result of its deliberation the Conference adopted the resolutions and specifications attached to this Report and set out in Schedule B, and requested the Delegates to lay them before their respective Governments with a view to obtaining uniformity in the legislation with regard to Electrical Units and Standards.

The Conference recommends the use of the Weston normal cell as a convenient means of measuring both electromotive force and current when set up under the conditions specified in Schedule C.

In cases in which it is not desired to set up the standards provided in the resolutions Schedule B, the Conference recommends the following as working methods for the realisation of the international ohm, the ampere, and the volt:—

1. *For the International Ohm.*

   The use of copies, constructed of suitable material and of suitable form verified from time to time, of the international ohm, its multiples and submultiples.

2. *For the International Ampere.*

   (*a*) The measurement of current by the aid of a current balance standardised by comparison with a silver voltameter; or

   (*b*) The use of a Weston normal cell whose electromotive force has been determined in terms of the international ohm and international ampere, and of a resistance of known value in international ohms.

3. *For the International Volt.*

   (*a*) A comparison with the difference of electrical potential between the ends of a coil of resistance of known value in international ohms, when carrying a current of known value in international amperes; or

   (*b*) The use of a Weston normal cell whose electromotive force has been determined in terms of the international ohm and the international ampere.

The duties of specifying more particularly the conditions under which these methods are to be applied has been assigned to the Permanent Commission, and, pending its appointment, to the Scientific Committee to be nominated by the President (*see* Schedule D), who will issue a series of Notes as Appendix to this Report.

The Conference has considered the methods that should be recommended to the Governments for securing uniform administration in relation to electrical units and standards, and expresses the opinion that the best method of securing uniformity for the future would be by the establishment of an international electrical laboratory with the duties of keeping and maintaining international electrical standards. This laboratory to be equipped entirely independently of any national laboratory.

The Conference further recommends that action be taken in accordance with the scheme set out in Schedule D.

Signed at London on October 21, 1908,
by the Delegates of the Countries above written.

For the United States of America.—S. W. Stratton, Henry S. Carhart, and Edward B. Rosa.

For Austria.—Victor Von Lang and Ludwig Kusminsky.

For Belgium.—P. Clément.

For Brazil.—Leopold J. Weiss.

For Chile.—Victor Eastman.

For Colombia.—Jorge Roa.

For Denmark and Sweden.—Svante Arrhenius.

For Ecuador.—C. Nevares.

For France.—G. Lippmann, J. René Benoît, and T. De Nerville.

For Germany.—E. Warburg, W. Jaeger, and St. Lindeck.

For Great Britain.—Rayleigh, J. Gavey, R. T. Glazebrook, W. A. J. O'Meara, A. P. Trotter, and J. J. Thomson.

For Guatemala.—Francisco de Arce.

For Hungary.—Harsanyi Desiré and Vater Joisef.

For Italy.—Antonio Ròiti.

For Japan.—Osuke Asano and Shigeru Kondo.

For Mexico.—Alfonso Castelló.

For Netherlands.—Dr. H. Haga.

For Paraguay.—Max. F. Croskey.

For Russia.—N. Egoroff and L. Swentorzetzky.

For Spain.—Jose Ma. de Madariaga and A. Montenegro.

For Switzerland.—Dr. H. F. Weber, P. Chappuis, and Jean Landry.

For Australia.—C. W. Darley and — Threlfall.

For Canada.—Ormond Higman.

For Crown Colonies.—P. Cardew.

For India.—M. G. Simpson.

In the presence of—M. J. Collins, W. Duddell, C. W. S. Crawley, and F. E. Smith, Secretaries.

SCHEDULE A.

List of Countries and Delegates.

America (United States).—Dr. S. W. Stratton, Director Bureau of Standards, Washington; Dr. Henry S. Carhart, Professor of Physics at the University of Michigan; and Dr. E. B. Rosa, Physicist, Bureau of Standards, Washington.

Austria.—Dr. Viktor Edler von Lang, President of the Commission of Weights and Measures, Vienna; and Dr. Ludwig Kusminsky, Inspector of above Commission.

Belgium.—Professor Eric Gérard, Director of the Montefiore Electro-Technical Institution and President of the Consultative Commission on Electricity; and Monsieur Clément, Secretary of the Consultative Commission on Electricity.

Brazil.—Mr. L. Weiss, Chef de la Section Technique des Telegraphes, Brésil.

Chile.—Don Victor Eastman, First Secretary to the Legation of Chile, London.

Colombia.—Don Jorge Roa.

Denmark and Sweden.—Professor S. A. Arrhenius, Nobel Institute, Stockholm.

Ecuador.—Señor Don Celso Nevares, Consul-General.

France.—Professor Lippmann, Member of the Institute and Professor at the Sorbonne; M. R. Benoît, Directeur du Bureau International des Poids et Mesures; and M. de Nerville, Ingénieur en Chef des Télégraphes.

Germany.—Professor Warburg, President of the Imperial Physico-Technical Institute; Professor Jaeger, Member of the Imperial Physico-Technical Institute; and Professor Lindeck, Member of the Imperial Physico-Technical Institute.

Great Britain.—The Right Hon. Lord Rayleigh, President of the Royal Society; Professor J. J. Thomson, F.R.S., Cambridge; Sir

John Gavey, C.B.; Dr. R. T. Glazebrook, F.R.S., Director of the National Physical Laboratory; Major W. A. J. O'Meara, C.M.G., Engineer-in-Chief General Post Office; and Mr. A. P. Trotter, Electrical Adviser to the Board of Trade.

Guatemala.—Dr. Francisco de Arce, Diplomatic Representative, London and Paris.

Hungary.—Joseph Váter, Director Technique des Postes and des Telegraphes, Budapest; and Dr. Desiré Harsanyi, Director of the Hungarian Royal Commission for Weights and Measures.

Italy.—Professor Antonio Ròiti, of Florence.

Japan.—Dr. Osuke Asano, Doctor of Engineering, Official Expert of the Department of Communications, Tokyo; and Mr. Shigeru Kondo, Official Expert of the Department of Communications, Tokyo,

Mexico.—Don Alfonso Castelló and Don José Maria Perez.

Netherlands.—Dr. H. Haga, Professor at the University of Groningen.

Paraguay.—M. Maximo Croskey.

Russia.—Dr. N. Egoroff, D.Sc., Director of the General Chamber of Weights and Measures; and Col. L. Swentorzetzky, Ingénieur Militaire, Prof. de l'Academie Militaire Nicolas des Ingénieurs, St. Petersburg.

Spain.—Don José Maria Madariaga, Professor of Electricity and Physics at the School of Mines, Madrid; and Don. A. Montenegro, Ingénieur Professor du Laboratoire de l'Ecole de Mines, Madrid.

Switzerland.—Dr. Fr. Weber, Professor at the Swiss Polytechnic School at Zurich; Dr. Pierre Chappuis, Membre Honoraire du Bureau International des Poids et Mesures; and Dr. J. Landry, Professor of Industrial Electricity in the University, Lausanne.

British Colonies.—Australia: Mr. Cecil W. Darley, I.S.O., late Inspecting and Consulting Engineer New South Wales Government; and Professor Threlfall, M.A., F.R.S. Canada: Mr. Ormond Higman, Chief Electrical Engineer Electric Standards Laboratory, Ottawa. Crown Colonies: Major P. Cardew, Electrical Adviser. India: Mr. M. G. Simpson, Electrician of the Indian Telegraph Department.

Secretaries: Mr. M. J. Collins, Mr. W. Duddell, F.R.S., Mr. C. W. S. Crawley, and Mr. F. E. Smith.

SCHEDULE B.

Resolutions.

I. The Conference agrees that, as heretofore, the magnitudes of the fundamental electric units shall be determined on the electro-magnetic system of measurement with reference to the centimetre as the unit of length, the gramme as the unit of mass, and the second as the unit of time.

These fundamental units are (1) the ohm, the unit of electric resistance which has the value of 1,000,000,000 in terms of the centimetre and second; (2) the ampere, the unit of electric current which has the value of one-tenth (0·1) in terms of the centimetre, gramme, and the second; (3) the volt, the unit of electromotive force which has the value 100,000,000 in terms of the centimetre, the gramme, and the

second; (4) the watt, the unit of power which has the value 10,000,000 in terms of the centimetre, the gramme, and the second.

II. As a system of units representing the above, and sufficiently near to them to be adopted for the purpose of electrical measurements and as a basis for legislation, the Conference recommends the adoption of the international ohm, the international ampere, and the international volt defined according to the following definitions:—

III. The ohm is the first primary unit.

IV. The international ohm is defined as the resistance of a specified column of mercury.

V. The international ohm is the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice, 14·4521 grammes in mass, of a constant cross-sectional area and of a length of 106·300 centimetres.

To determine the resistance of a column of mercury in terms of the international ohm, the procedure to be followed shall be that set out in Specification I. attached to these Resolutions.

VI. The ampere is the second primary unit.

VII. The international ampere is the unvarying electric current which, when passed through a solution of nitrate of silver in water, in accordance with Specification II. attached to these Resolutions, deposits silver at the rate of 0·00111800 of a gramme per second.

VIII. The international volt is the electrical pressure which, when steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampere.

IX. The international watt is the energy expended per second by an unvarying electric current of one international ampere under an electric pressure of one international volt.

Specification I.

Specification relating to Mercury Standards of Resistance.

The glass tubes used for mercury standards of resistance must be made of a glass such that the dimensions may remain as constant as possible. The tubes must be well annealed and straight. The bore must be as nearly as possible uniform and circular, and the area of cross-section of the bore must be approximately one square millimetre. The mercury must have a resistance of approximately one ohm.

Each of the tubes must be accurately calibrated. The correction to be applied to allow for the area of the cross-section of the bore not being exactly the same at all parts of the tube must not exceed 5 parts in 10,000.

The mercury filling the tube must be considered as bounded by plane surfaces placed in contact with the ends of the tube.

The length of the axis of the tube, the mass of mercury the tube contains, and the electrical resistance of the mercury are to be determined at a temperature as near to 0° C. as possible. The measurements are to be corrected to 0° C.

For the purpose of the electrical measurements, end vessels carrying connections for the current and potential terminals are to be fitted on to the tube. These end vessels are to be spherical in shape (of a diameter of approximately four centimetres) and should have cylindrical

pieces attached to make connections with the tubes. The outside edge of each end of the tube is to be coincident with the inner surface of the corresponding spherical end vessel. The leads which make contact with the mercury are to be of thin platinum wire fused into glass. The point of entry of the current lead and the end of the tube are to be at opposite ends of a diameter of the bulb; the potential lead is to be midway between these two points. All the leads must be so thin that no error in the resistance is introduced through conduction of heat to the mercury. The filling of the tube with mercury for the purpose of the resistance measurements must be carried out under the same conditions as the filling for the determination of the mass.

The resistance which has to be added to the resistance of the tube to allow for the effect of the end vessels is to be calculated by the formula—

$$A = \frac{0{\cdot}80}{1063\pi}\left(\frac{1}{r_1} + \frac{1}{r_2}\right) \text{ ohm},$$

where r_1 and r_2 are the radii in millimetres of the end sections of the bore of the tube.

The mean of the calculated resistances of at least five tubes shall be taken to determine the value of the unit of resistance.

For the purpose of the comparison of resistances with a mercury tube the measurements shall be made with at least three separate fillings of the tube.

Specification II.

Specification relating to the Deposition of Silver.

The electrolyte shall consist of a solution of from 15 to 20 parts by weight of silver nitrate in 100 parts of distilled water. The solution must only be used once, and only for so long that not more than 30 per cent. of the silver in the solution is deposited.

The anode shall be of silver, and the kathode of platinum. The current density at the anode shall not exceed 1/5 ampere per square centimetre and at the kathode 1/50 ampere per square centimetre.

Not less than 100 cubic centimetres of electrolyte shall be used in a voltameter.

Care must be taken that no particles which may become mechanically detached from the anode shall reach the kathode.

Before weighing, any traces of solution adhering to the kathode must be removed, and the kathode dried.

SCHEDULE C.

Weston Normal Cell.

The Weston normal cell may be conveniently employed as a standard of electric pressure for the measurement both of E.M.F. and of current, and, when set up in accordance with the following specification, may be taken, provisionally,[1] as having, at a temperature of 20° C., an E.M.F. of 1·0184 volt.

[1] See duties of the Scientific Committee, Schedule D.

The Weston normal cell is a voltaic cell which has a saturated aqueous solution of cadmium sulphate ($CdSO_4.8/3\ H_2O$) as its electrolyte.

The electrolyte must be neutral to congo red.

The positive electrode of the cell is mercury.

The negative electrode of the cell is cadmium amalgam consisting of 12·5 parts by weight of cadmium in 100 parts of amalgam.

The depolariser, which is placed in contact with the positive electrode, is a paste made by mixing mercurous sulphate with powdered crystals of cadmium sulphate and a saturated aqueous solution of cadmium sulphate.

The different methods of preparing the mercurous sulphate paste are described in the notes.[1] One of the methods there specified must be carried out.

For setting up the cell, the **H** form is the most suitable. The leads passing through the glass to the electrodes must be of platinum wire, which must not be allowed to come into contact with the electrolyte. The amalgam is placed in one limb, the mercury in the other.

The depolariser is placed above the mercury and a layer of cadmium sulphate crystals is introduced into each limb. The entire cell is filled with a saturated solution of cadmium sulphate and then hermetically sealed.

The following formula is recommended for the E.M.F. of the cell in terms of the temperature between the limits 0° C. and 40° C. :—

$$E_t = E_{20} - 0{\cdot}0000406(t-20^\circ) - 0{\cdot}00000095(t-20^\circ)^2 + 0{\cdot}00000001(t-20^\circ)^3.$$

SCHEDULE D.

1. The Conference recommends that the various Governments interested establish a permanent International Commission for Electrical Standards.

2. Pending the appointment of the Permanent International Commission, the Conference recommends [2] that the President, Lord Rayleigh, nominate for appointment by the Conference a Scientific Committee of fifteen to advise as to the organisation of the Permanent Commission, to formulate a plan for and to direct such work as may be necessary in connection with the maintenance of standards, fixing of values [3], inter-comparison of standards, and to complete the work

[1] Notes on methods pursued at various standardising laboratories will be issued by the Scientific Committee or the Permanent Commission, as an Appendix to this Report.

[2] In accordance with the above, Lord Rayleigh has nominated the following Committee, which has been approved by the Conference, viz. :—

Dr. Osuke Asano.	Dr. H. Haga.	Dr. E. B. Rosa.
M. R. Benoît.	D. L. Kusminsky.	Dr. S. W. Stratton.
Dr. N. Egoroff.	Prof. St. Lindeck.	Mr. A. P. Trotter.
Prof. Eric Gérard.	Prof. G. Lippmann.	Prof. E. Warburg.
Dr. R. T. Glazebrook.	Prof. A. Ròiti.	Prof. Fr. Weber.

[3] This will include the reconsideration from time to time of the E.M.F. of the Weston normal cell.

of the Conference.[1] Vacancies on the Committee to be filled by co-optation.

3. That laboratories equipped with facilities for precise electrical measurements and investigations should be asked to co-operate with this Committee and to carry out, if possible, such work as it may desire.

4. The Committee should take the proper steps forthwith for establishing the Permanent Commission, and are empowered to arrange for the meeting of the next Conference on Electrical Units and Standards, and the time and place of such meeting should this action appear to them to be desirable.

5. The Committee or the Permanent International Commission shall consider the question of enlarging the functions of the International Commission on Weights and Measures, with a view to determining if it is possible or desirable to combine future Conferences on Electrical Units and Standards with the International Commission on Weights and Measures, in place of holding in the future Conferences on Electrical Units and Standards. At the same time it is the opinion of the Conference that the Permanent Commission should be retained as a distinct body, which should meet at different places in succession.

Seismological Investigations.—Fourteenth Report of the Committee, consisting of Professor H. H. TURNER (*Chairman*), Dr. J. MILNE (*Secretary*), Mr. C. VERNON BOYS, Sir GEORGE DARWIN, Mr. HORACE DARWIN, Major L. DARWIN, Dr. R. T. GLAZEBROOK, Mr. M. H. GRAY, Professor J. W. JUDD, Professor C. G. KNOTT, Professor R. MELDOLA, Mr. R. D. OLDHAM, Professor J. PERRY, Mr. W. E. PLUMMER, Professor J. H. POYNTING, Mr. CLEMENT REID, *and* Mr. NELSON RICHARDSON. (*Drawn up by the Secretary.*)

[PLATE I.]

CONTENTS.

I. *General Notes.*

LAST year, early in November, my assistant, Mr. H. C. O'Neill, left me for an appointment in London. The last work on which he was

[1] With this object the Committee are authorised to issue as an Appendix to the Report of the Conference, Notes detailing the methods which have been adopted

engaged when in the Isle of Wight was a catalogue of the Shide collection of papers bearing upon seismology written in foreign languages. Although he continued this compilation while in London, I regret to say that the completion of the same has for the time being been interfered with by ordinary routine work. As illustrative of this latter I may take the map which accompanies each report and shows the distribution of earthquake centres for the previous twelve months. Inasmuch as the production of this sheet involves the consideration and usually a calculation based upon each of the entries of all co-operating stations, it will be understood that much time is spent in the production of what is shown as a single plate. Correspondence with stations and those interested in our work occasionally occupies a morning. Each day films and other record-receiving surfaces have to be renewed. Films have to be developed, measured, and records reduced to a form suitable for publication. The registers from all co-operating stations have to be recopied and classified. Accurate time has to be kept, and attention has to be given to the ordinary meteorological instruments found in most observatories. Between the hours of 8 A.M. and 10 P.M. we are usually able to give information bearing upon our work. My assistants work in the morning and again in the evening, and, when occasion requires, also in the afternoon. The amount of original work done in the laboratory is outlined in the Reports.

Registers.—During the past year the registers issued are contained in Circulars Nos. 18 and 19. These refer to Shide, Kew, Bidston, Edinburgh, Paisley, Haslemere, San Fernando (Spain), Valetta (Malta), Cairo, Beirût, Ponta Delgada, Cape of Good Hope, Calcutta, Bombay, Kodikânal, Irkutsk, Batavia, Trinidad, Lima, Baltimore, Toronto, Victoria, B.C., Honolulu, Perth, Sydney, Christchurch, and Mauritius.

High-speed (24 cm. per hour) record-receiving apparatus has been sent to Edinburgh and to Lima. Similar apparatus will be sent to San Fernando (Spain). It is expected that the Naturalists' Society of Cardiff will shortly put up a seismograph.

For a continuation of financial support I again thank the Royal Society, the British Association, the administrators of the Gray Fund, and Mr. Richard Cooke. I regret to say the support I received from the 'Daily Mail' has ceased. The chief expenditure relates to salaries and material. With the latter there is included the cost of photographic films required at Bidston.

The Committee ask for reappointment and a grant of 60*l.*

II. *Sites of Stations.*

Eskdalemuir Magnetic Observatory, Dumfriesshire, Scotland.

Main Building, Latitude	55° 18′	42·2″ N.
" Longitude	3° 12′	19·7″ W.
" Height	775·29 feet.	
Level of Davington Burn about 700 feet.		

Geological formation consists of rocks of the Tarannon Llandovery series transversed by igneous dykes.

in the Standardising Laboratories of the various countries to realise the International Ohm and the International Ampere, and to set up the Weston normal cell.

The seismograph room is situated on the ground floor of the main office building. The principal pier is built of solid cubes of sandstone, and passes directly to the rock at a depth of 21 feet. The pier is enclosed in a brick well to isolate it from local surface movements. The Milne twin-boom instrument is mounted on this pier, so as to give N.S. and E.W. components. The period of the booms is about 18 seconds, and at this period the scale is 1 mm. $=0''\cdot391$.

A spare pier is also situated in the room, and will be used for research work on the behaviour of other forms of seismographs.

Toronto, Canada.—When the magnetometers, on account of interference with electric trains, were moved from Toronto to Agincourt the seismograph was moved also. The underlying rocks at Agincourt are the same as those at Toronto, about nine miles distant. These are Hudson River shales, covered with a thick deposit of alluvium. These latter drift deposits no doubt differ to a certain degree, but there are no sections at Agincourt which can be compared with those at Toronto. It may be mentioned that when the magnetometers were in Toronto they did not appear to have been disturbed at the time of large earthquakes. Now that these instruments are removed to Agincourt from time to time they show irregularities which may be due to teleseismic movement (see 'B. A. Reports,' 1898, p. 237; 1899, p. 170).

Porto Rico, W. Indies.—The instrument at this station is of the Bosch-Omori type and forms part of the equipment of the United States Coast and Geodetic Survey. It is established at the Magnetic Observatory situated on Vieques Island, east of the island of Porto Rico. It is mounted in the north-east corner room on the ground floor of the old Spanish fort 'Isabel.' The floor of the room consists of 3 inches of cement underlaid with 3 inches of hard clay, which in turn is underlaid by stone. The piers, four in number, on which the seismograph parts are mounted are each 20 inches square by 32½ inches deep. Each consists of three pieces of dressed stone. These are laid in cement and extend 30 inches below floor-level; the space round each pier is filled with cement within 4 inches of the floor. The instrument consists of two pendulums recording north-south and east-west motion. It is possible to obtain the time of any effect within one or two seconds. The paper moves 15 mm. to the minute. The period of north-south pendulum is 26·36 seconds; east-west pendulum 24·7 seconds. The multiplication of the tracing points is 10.

Stonyhurst, near Blackburn, North Lancashire, England.—The latitude of the observatory is 53° 50′ 40″ N; longitude, 0° 52′ 68″ W of Greenwich. The seismograph is the one which was used for two years in the Antarctic regions by the officers of the s.s. *Discovery*. The standard and other parts of the instrument are made of gunmetal and non-magnetic materials. At Stonyhurst it is installed in the underground magnetic chamber, which is dry and does not suffer from variations of temperature. It is placed on a pillar composed of two cut stones firmly cemented together. On the top of these there is a slate slab also cemented to the uppermost stone. The pillar is embedded in and rests upon 12 inches of concrete below the stone floor of the chamber. The concrete rests on hard clayey soil. The height of the top of the slab from the floor is 3½ feet, and its height above sea-level is 364 feet.

Origins for 1908 are indicated by their B.A. Shide Register number. Earthquake districts are indicated A, B, C, &c., and the number of Earthquakes since 1899 which originated from these is expressed in large numerals.

Illustrating the Report on Seismological Investigations

III. *The Large Earthquakes of* 1908.

The distribution of origins for the large earthquakes of 1908 is very similar to that of 1907. The greatest activity has been at the overlap of districts E and F. In the totals for districts the earthquakes for the E F overlap have been regarded as belonging to E and not to F. Earthquake No. 1603 is included in the total for H, and Nos. 1568 and 1602 in those for K. The correct number of District C for 1906 is 27 and not 29 (see map and Report for 1907).

In studying these districts it must be remembered that they merge one into the other, and cannot be regarded as so many strictly defined isolated elliptical areas. C, H, K, and F may, for example, be looked upon as districts of marked activity along a band which extends nearly round the world, while D, B, A, E represent areas of marked intensity on a band which fringes a great part of the Pacific Ocean.

The total number of earthquakes which have occurred in 1908 on the east side of the Pacific is slightly greater than those which occurred in 1907. A similar increase is noted for the west side of the same ocean.

A table published in the 'B. A. Reports,' 1908, p. 63, shows that for the years 1899 to 1907 inclusive the greatest megaseismic activity has prevailed in the East Indian Archipelago, and the least on the West Coast of South America. If, instead of comparing the activity in the large districts which are indicated on the accompanying map (Plate I.) by the letters A, B, C, &c., we compare the number of large earthquakes which have originated during the last ten years within areas each about five degrees radius, the results arrived at are as follow:—

Centre	120° E. 5° N.	gave	75	large earthquakes.
,,	140° E. 40° N.	,,	68	,, ,,
,,	70° E. 25° N.	,,	40	,, ,,
,,	145° W. 45° N.	,,	33	,, ,,

These figures indicate that at the present time the most pronounced centres of seismic activity are to be found in the centre of the East Indian Archipelago and from the East Coast of Central Japan south-westwards towards Formosa. The first of these is near to the junction of two pronounced lines of folding in the earth's crust.

IV. *After-shocks of the Earthquake at Jamaica, January* 14, 1907.

In the Report for 1908, p. 64, reference is made to 148 after-shocks which in 1907 were recorded between January 14 and July 5, in Jamaica; ninety-two of these appear to have been recorded in the Isle of Wight. The time taken for earth waves to travel from Jamaica to the Isle of Wight, a distance of 67 degrees, would be about forty-three minutes, and it is at this interval of time subsequent to shocks in Jamaica that we find thickenings and sinuosities in seismograms obtained in Britain. A large number of these records are also to be found on seismographic traces obtained at Bidston, Kew, Paisley, and Edinburgh. This concurrence of records from different stations and the particular times at which they occur in reference to the times of origin of shocks in Jamaica lead us to the conclusion that comparatively small shocks may with suitable instruments be recorded at localities several thousands of miles distant from their origin. The

particular group of records to which we refer are given in the accompanying table. The entry of July 5 may have been recorded at Göttingen, but with this exception the remaining disturbances do not appear in registers from Göttingen, Strassburg, or Laibach. The difference in the number of records obtained at different stations where the instruments are of one type, viz., that adopted by the British Association, partly finds an explanation in differences in foundation, see p. 60. The reasons that stations provided with apparatus of the Reuber-Ehlert type do not appear to pick up very small movements is possibly due to a want of definition in the photographic trace; but here again the question of foundation cannot be overlooked. Directly we come to apparatus where the record is obtained upon a smoked surface, which is the case at many European and American stations, a new factor has to be considered. The slight freedom in the connections between the joints of multiplying indices, and the elasticity of the same, suggests a loss of motion, the result being that the writing pointers do not move until a certain amplitude of earth movement has been reached. Whether this explanation be correct or not, my own experience is that instruments writing on a smoked surface, although they may yield excellent seismograms of a large earthquake, are very unsatisfactory as recorders of very slight disturbances. Records of large earthquakes may be obtained by many types of instruments, but directly we wish to record feeble movements at considerable distances from their origin, the best results appear to come from the instrument adopted by the British Association with the photographic surface moving at the rate of about 240 mm. per hour. As illustrative of this we find that the number of records obtained at Shide, Hamburg, Göttingen, and Laibach between January 1 and April 30 of this year were respectively 98, 65, 61, and 33. At the first of these stations the instrument employed is of the B.A. type, whilst at the three latter stations records are obtained on smoked paper or by photographic arrangements with a high multiplication. All the records referred to were noted at more than one station, and therefore their reality as representing widespread earth disturbances cannot be doubted. The number of records obtained at Bidston, Kew, and Edinburgh, where the photo-receiving surface only moves at the rate of 60 mm. per minute, were not so numerous as those obtained at Shide.

After-shocks of the Jamaica Earthquake apparently recorded in Great Britain.

Date	Due in England	Shide	Kew	Bidston	Paisley	Edinburgh
1907						
Jan. 15 .	0.55	—	—	—	—	0.48 ?
" .	1.53	1.52	—	1.52	—	—
" .	2.52	2.53	—	2.52	2.52	2.48
" .	3.50	3.51	—	3.51	—	3.51
" .	5.5	5.4	—	4.58 ?	—	—
" .	7.30	7.40	—	7.27	7.25	7.25
" .	8.50	8.50	8.44	8.52	8.50	—
" .	9.20	9.19	9.29	9.19	—	9.21
" .	11.50	11.45	—	11.43	11.45	—
" .	15.50	15.45	—	—	15.45	—
" .	17.15	17.14	—	17.14	17.15	—
" .	17.48	18.12	17.48	18.16	18.12	—
" .	21.52	—	—	—	—	—

After-shocks of the Jamaica Earthquake—continued.

Date	Due in England	Shide	Kew	Bidston	Paisley	Edinburgh
1907						
Jan. 15 .	22.31	22.35	—	—	—	—
Jan. 16 .	5.19	—	—	—	—	—
,, .	8.45	8.45	—	—	—	8.46
,, .	17.24	17.19	17.18	17.20	17.17	—
,, .	22.24	22.48	—	22.23	—	—
Jan. 17 .	2.50	2.45	—	—	—	—
,, .	6.5	6.6	—	—	—	—
,, .	13.40	13.37	—	13.44	—	—
,, .	17.20	17.19	17.18	17.20	17.18	—
,, .	22.47	—	—	—	—	—
Jan. 18 .	3.25	Ats.	—	?	—	—
,, .	7.20	,,	—	7.25?	—	—
,, .	11.50	,,	—	11.44	—	—
,, .	12.24	,,	—	12.30?	—	—
,, .	14.20	,,	—	—	—	—
,, .	17.20	17.20	—	17.20	17.20	17.21
,, .	18.20	—	—	—	—	—
,, .	19.50	19.55	—	19.59	—	—
,, .	21.50	—	—	22 21?	—	—
Jan. 19 .	8.50	8.50	—	8.50	8.49	8.48
,, .	10.59	?	—	11.0	—	—
,, .	11.20	11.22	—	11.22	—	—
,, .	15.20	15.22	—	—	—	—
,, .	16.40	16.35	16.36	16.34	16.40	—
Jan. 20 .	1.20	1.24	—	1.26?	—	—
,, .	3.10	3.7	—	3.3?	—	—
,, .	3.50	3.53	—	—	—	—
,, .	4.20	4.12	—	4.16	—	—
,, .	9.5	9.6	—	—	—	—
,, .	12.12	—	—	—	—	—
,, .	17.50	17.45	—	—	—	—
,, .	20.22	—	—	—	—	—
,, .	21.20	—	—	—	—	—
,, .	22.35	—	—	—	—	—
Jan. 21 .	4.50	—	—	—	—	—
,, .	18.45	—	—	—	—	—
,, .	23.50	23.45	—	—	—	—
Jan. 22 .	3.20	3.21	—	3.24?	—	—
,, .	13.50	13.52	—	—	—	—
,, .	20.5	Ats.	—	—	—	—
,, .	20.25	,,	—	—	—	—
,, .	22.0	22.3	—	21.56	—	—
Jan. 23 .	3.10	3.9	—	—	—	—
,, .	6.50	6.52	—	6.49	—	—
,, .	10.45	10.36	—	—	—	—
,, .	15·13	15.12	—	—	—	—
Jan. 24 .	9.50	—	—	—	—	—
,, .	15.35	—	—	15.50?	—	—
,, .	16.10	16.18	—	—	—	—
,, .	20.25	—	—	—	—	—
Jan. 26 .	16.55	16.50	—	—	—	—
,, .	19.35	—	—	—	—	—
Jan. 27 .	14.50	14.50	—	—	—	—
Jan. 28 .	9.30	—	—	—	—	—
,, .	10.23	10.18	10.23	10.18	10.18	10.25
,, .	13.50	13.53	—	13.53	13.52	—
Jan. 29 .	4.1	—	—	4.2?	—	—
,, .	18.55	—	—	18.53	—	—
Jan. 30 .	3.10	—	—	—	—	—

After-shocks of the Jamaica Earthquake—continued.

Date	Due in England	Shide	Kew	Bidston	Paisley	Edinburgh
1907						
Jan. 30 .	3.30	3.38	—	—	—	—
„ .	4.10	—	—	?	—	—
„ .	13.11	13.11	—	—	13.10	—
„ .	14.10	14.11	—	14.9	14.10	14.13
Feb. 1 .	1.50	—	—	—	—	—
Feb. 2 .	5.50	—	—	?	—	—
Feb. 3 .	5.45	5.44	—	—	—	—
„ .	5.55	6.7	—	—	—	—
„ .	8.2	8.0	—	—	—	—
Feb. 4 .	9.50	9.45	—	—	9.45	—
„ .	11.50	—	—	?	—	—
„ .	12.50	12.55	12.44	—	12.53	12.52
Feb. 5 .	7.20	7.11	7.25	—	7.10	—
„ .	11.5	11.15	—	—	11.14	11.5
Feb. 6 .	4.49	4.48	—	4.48	4.48	—
„ .	8.45	8 to 9	8.0	—	8 to 9	—
„ .	21.15	21.17	—	?	—	—
Feb. 7 .	4.50	4.52	—	4.54	—	—
Feb. 10 .	6.10	6.10	—	6.15	6.10	6.10
„ .	19.50	19.48	19.45	19.56	19.47	19.49
Feb. 11 .	6.20	—	—	?	—	—
„ .	23.20	23.22	23.24	23.20?	23.21	23·23
Feb. 18 .	3.40	3.41	—	—	—	—
Feb. 19 .	5.45	5.44	—	—	—	—
Feb. 22 .	14.33	—	—	14.22	—	—
Feb. 23 .	0.5	0.5	—	0.8	0.5	0.5
Feb. 26 .	23.30	—	—	—	—	—
Feb. 27 .	2.35	—	—	2.30	—	—
Feb. 28 .	5.30	—	—	5.25	—	—
„ .	13.30	13.35	—	—	13.31	—
Mar. 1 .	10.5	10.7	—	10.7	10.6	—
„ .	11.45	—	—	11.40	—	—
Mar. 2 .	6.35	—	—	—	—	—
„ .	5.35	—	—	—	—	—
Mar. 6 .	3.45	3.42	—	3.43	—	—
Mar. 7 .	12.2	12.3	—	?	—	—
„ .	13.50	13.58	—	—	—	—
Mar. 8 .	10.5	10.4	10.9	—	—	—
Mar. 9 .	11.35	11.30	11.23	—	11.29	—
Mar. 11 .	7.40	7.42	—	—	7.43	—
Mar. 15 .	4.50	4.53	—	—	4.53	—
Mar. 17 .	12.20	12.15	12.16	—	12.17	—
Mar. 18 .	1.35	1.20	—	1.35	1.19	1.30
Mar. 19 .	12.0	12.7	12.4	—	—	—
Mar. 21 .	5.49	—	—	—	—	—
Mar. 23 .	0.32	—	—	—	—	—
„ .	19.27	19.20	—	—	—	—
Mar. 24 .	4.25	—	—	—	—	—
Mar. 25 .	6.0	—	—	—	—	—
Mar. 27 .	14.45	14.40	14.41	—	14.40	—
Mar. 28 .	14.20	14.25	14.25	—	14.25	—
Mar. 31 .	13.0	—	—	13.4	—	—
April 2 .	10.50	—	—	?	—	—
April 9 .	8.35	—	—	8.30	—	—
April 10 .	3.20	—	—	—	—	—
April 11 .	12.4	12.4	—	12.1	—	—
April 13 .	4.50	—	—	—	—	—
„ .	12.58	12.58	—	12.50	—	—
April 16 .	12.50	12.52	12.49	—	12.55	—

After-shocks of the Jamaica Earthquake—continued.

Date	Due in England	Shide	Kew	Bidston	Paisley	Edinburgh
1907						
April 25 .	1.15	—	—	0.35	—	—
" .	9.50	—	—	?	—	—
April 28 .	2.53	—	—	—	—	—
" .	23.0	—	—	?	—	—
April 29 .	1.30	—	—	?	—	—
May 1 .	21.35	21.25	—	—	21.31	21.30
May 2 .	2.20	2.20	—	2.22	2.21	—
May 3 .	17.0	17.2	16.54	—	17.3	—
May 4 .	2.42	2.43	—	—	—	—
May 11 .	1.30	—	—	1.25	—	—
June 13 .	7.8	7.1	7.8	—	—	—
June 14 .	7.20	7.24	—	—	—	—
June 16 .	16.15	16.56	16.57	16.55	—	—
June 18 .	13.20	13.30	—	—	—	—
June 29 .	20.4	—	—	—	—	—
July 1 .	11.0	11.1	—	—	—	—
July 5 .	20.0	20.3	—	20.0?	—	—
Total. .	148	92	22	58	39	18

The movements recorded at Kew are referred to as being very small and ill-defined, and in the ordinary way would have been passed over as being due either to air tremors or some other non-seismic cause.

The records from Bidston are spoken of as 'doubtful,' 'possible,' 'very evident,' 'very pronounced,' and 'clearly marked.'

Paisley records were much interfered with by air tremors; it is therefore possible that some of the entries are non-seismic in character.

The Edinburgh records are spoken of as 'slight thickenings,' 'small notches,' 'roughness of line,' 'slight tremors.'

In the Report for this year the Shide list has been increased by 41 entries. These have been added because they have been confirmed by records from other stations.

V. *Quick Vibrators as applied to Seismometry.*

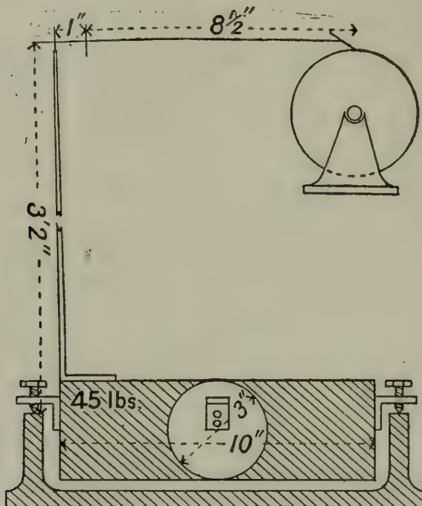
In a paper on 'A Neglected Principle that may be employed in Earthquake Measurements,' by Professors J. Perry and W. E. Ayrton (see 'Trans. Asiatic Soc. of Japan,' May 23, 1877), it is suggested that the essential feature in a seismograph should be a heavy mass so suspended by stiff springs that its own free period would be about five times as fast as that of an earthquake. This was to take the place of the steady point in modern seismographs. Inasmuch as this instrument was never constructed, we can only surmise about the character of the record it would furnish.

In a paper on 'Experiments in Observational Seismology' (see 'Trans. Seis. Soc.,' vol. iii. 1881) I make reference to pendulums the periods of which were a small fraction of a second. They were only used as tremor-indicators.

Notes on these and on other quick vibrators are referred to in the chapter on 'Seismometry' in a small volume on 'Earthquakes' published in the 'International Science Series,' 1883. All these instruments were intended to record earthquakes which could be felt, the periods of which varied between one and three or four seconds. As they merely

acted as seismoscopes, they quickly fell into disuse. To record unfelt teleseismic motion where the periods varied from about five to thirty seconds, I last year made the following experiment:—

A cylinder of lead 10 inches in length and ⅜ inch in diameter, weighing 45 lb., was suspended as shown in the accompanying sketch. From one end of the cylinder a light deal rod projected upwards. At its



upper end this engaged a light aluminium lever carrying a glass style resting on a drum covered with smoked paper. This multiplied the motion of the rod, which was 3 feet 2 inches in length, 8½ times. By this arrangement the equivalent of a rod 27 feet in length was obtained. The period of this pendulum with the style resting on the smoked paper was 0·6 second, or from eight to thirty times the period of the ground. During twenty-two days commencing November 26, although there were several earthquakes, two of which were distinctly large, no record was obtained. Possibly the multiplication was too small.

VI. *On a possible Synchronism between Seismic Activity in Different Districts.*

In the Report for 1908, p. 64, I pointed out that since 1902 seismic activity on the two sides of the North Pacific had fluctuated similarly. For example, registers show that when large earthquakes had been numerous on the East side of the Pacific they had also been numerous on the West side. To extend this inquiry, I have drawn up the following table giving the number of destructive earthquakes which have occurred between A.D. 1000 and A.D. 1650. They are grouped in periods of fifty years. Columns A, B, C, and D respectively refer to Japanese, Chinese, European, and Italian records. The letter ‘a’ indi-

cates that in two given districts seismic activity has been constant or has varied similarly, *i.e.*, there has been an *agreement.* The letter ' d ' indicates that there has been *disagreement.* For example, seismic activity may have increased in one district while it has decreased in another. As to whether an entry should be ' a ' or ' d,' no account has been taken of the greatness of increase or decrease in the number of earthquakes in the given period, but only whether it was a marked increase, decrease, or a period of quiescence. The columns in which the letters ' a ' and ' d ' occur are headed A to B, A to C, &c. If written more fully these would become A compared with B, A compared with C, &c.

Inasmuch as the Italian records are included in and form a large portion of those which refer to Europe generally, the comparison of C to D is of slight value. The general result indicates that in a period of 650 years we have had forty-four instances of agreements against twenty-eight instances of disagreements in the fluctuations in seismic activity in widely separated districts. This suggests that for the most part periods

Date	A	B	C	D	A to B	A to C	A to D	B to C	B to D	C to D	Totals. a	Totals. d
1000 to 1050	8	28	7	1								
1100	8	27	9	2	*a*	*a*	*a*	*a*	*a*	*a*	6	0
1150	3	11	8	5	*a*	*d*	*d*	*d*	*d*	*d*	1	5
1200	12	22	13	7	*a*	*a*	*a*	*a*	*a*	*a*	6	0
1250	7	13	7	6	*a*	*a*	*a*	*a*	*a*	*a*	6	0
1300	4	8	7	10	*a*	*d*	*d*	*d*	*d*	*d*	1	5
1350	8	64	12	3	*a*	*a*	*d*	*a*	*d*	*d*	3	3
1400	9	37	11	6	*d*	*a*	*a*	*d*	*d*	*d*	2	4
1450	13	16	18	5	*d*	*a*	*d*	*d*	*a*	*d*	2	4
1500	16	50	14	9	*a*	*d*	*a*	*d*	*a*	*d*	3	3
1550	6	49	16	9	*d*	*d*	*d*	*a*	*a*	*a*	3	3
1600	5	52	16	10	*a*	*a*	*d*	*a*	*a*	*a*	5	1
1650	10	60	25	13	*a*	*a*	*a*	*a*	*a*	*a*	6	0
					9*a* 3*d*	8*a* 4*d*	6*a* 6*d*	7*a* 5*d*	8*a* 4*d*	6*a* 6*d*	44*a*	28*d*

of seismic quiescence or of activity in various parts of the globe occur about the same time. This result does not, however, appear to be shown if we take eleven or thirty-three year periods. Of fifty-three periods of eleven years, A.D. 1000 to A.D. 1583, a comparison of the earthquakes of Europe with those of China and Japan respectively indicate that agreements and disagreements are about equally divided. A similar result is obtained when thirty-three year periods were taken for comparison of European and Japanese and Chinese and Japanese earthquakes.

Another method of determining whether there has been a time agreement in seismic activity in distant districts has been to plot year by year the large earthquakes of Japan and Italy on squared paper. The interval considered for each of these countries has been the last three hundred years. England and many other countries have been excluded because their records are few in number and only refer to comparatively feeble shocks. The two Americas have been omitted because their

registers are incomplete; Australia and New Zealand, because prior to 1850 we were without knowledge; and China, because its accessible registers end about 1644.

All materials prior to A.D. 1600 have been discarded on account of their fragmentary character, and it is often impossible to say whether certain entries refer to destructive earthquakes or only to comparatively small tremors. The only earthquakes considered are those which have been destructive, and these are divided into the following three classes: (I.) shocks which have cracked walls or damaged chimneys; (II.) shocks which have destroyed a few buildings; (III.) shocks which have caused widespread disaster. For Italy and for Japan these three classes have been taken separately, in pairs, and *en bloc*. Which ever way we have plotted them one result is clear, viz., in each of these two widely separated districts during the last three hundred years there have been periods of activity and periods of comparative rest. When the zigzag lines which show frequency from year to year are smoothed to curves you obtain a series of undulations the crests of which are separated from each other by periods varying between five and twenty years. There is no indication of a recurrence of activity after regular or equal intervals of time. The following table gives dates for the crests of these waves. In comparing any two of these dates it must be remembered that either of them might be increased or decreased by a year. The reason for this is twofold. First, an earthquake or earthquakes which occurred at the end of a year might, for the purposes of this investigation, have been assigned to the year following. Similarly, those which occurred in January of a given year might have been referred to the previous year. Also, it is difficult to determine the exact position for the crest of a wave. An inspection of the table shows for Italy eighteen dates for wave-crests, and fourteen of these agree very closely with dates indicating periods of seismic activity in Japan. These coincidences suggest that a relief of seismic strain in one part of the world either brings about a relief in some other part, or that relief is governed by some general internal or external agency.

Periods of Seismic Activity.

Japan	Italy	Differences	Japan	Italy	Differences
		Year			Year
1613	1612	1	1751	1755	4
—	1626	—	1765	1767	2
1644	1642	2	1782	1784	2
1663	1660	3	—	1798	—
1697	1693	4	1803	1806	3
1704	1703	1	1834	1833	1
1717	1717	0	1856	1856	0
1728	1728	0	—	1873	—
—	1744	—	1898	1896	2

VII. *The Time of Maximum Motion as indicated by Three differently installed Horizontal Pendulums.*

The three pendulums are the Milne type (see 'B.A. Report,' 1902, p. 60). Pendulum A records east-west motion; it stands on a brick column, the cross-section of which is 18 inches by 18 inches.

Pendulum B also records east-west motion; it stands near to A on another brick column. The cross-section of this is 18 inches by 37 inches.

Pendulum C records north-south motion; it is installed on the same column as B. The stiffness of these two piers, as might be inferred from their dimensions, are very different. In an east and west direction the B-C column is approximately four times as stiff as A column (see 'B.A. Report,' 1902, p. 60).

For certain intervals of time, each of several months' duration, these pendulums have been adjusted to have the same or different periods. When A and B had the same period, had they been loaded equally and installed on the same support we should expect that they would have attained a maximum swing at the same time. The following analyses show how far this was the case, notwithstanding the absence of this equality of conditions. With the object of comparing similar phases of motion, in all instances where time measures are concerned, reference has been made to the original seismograms. The earthquakes considered are indicated in the Shide Registers by the following numbers:—

666, 671, 672, 674, 676, 679, 686, 690, 694, 704, 705, 794, 806, 876, 832, 839, 859, 860, 861, 863, 872, 877, 884, 886, 900, 903, 904, 924, 952, 975, 977, 982, 990, 994, 1001, 1020, 1021, 1031, 1038, 1045, 1046, 1048, 1057, 1064, 1065, 1070, 1074, 1087, 1111, 1118, 1135, 1145, 1164, 1182, 1190, 1208, 1225, 1242, 1257, 1266, 1281, 1284, 1293, 1303, 1319, 1320, 1322, 1323, 1362, 1363, 1375, 1387, 1390, 1393, 1408, 1412, 1419, 1422, 1425, 1428, 1431, 1433, 1439, 1450, 1460, 1463, 1468, 1471, 1475, 1495, 1496, 1515, 1522, 1526, 1532, 1540, 1544, 1549, 1563, 1564, 1568, 1575, 1577, 1585, 1591.

No. 1.—For thirty-seven earthquakes A and B have had the same periods. For twenty-five of these a maximum motion was recorded at the same time; for the remaining twelve earthquakes the difference in time for the maximum swing was two minutes or over.

No. 2.—For twenty earthquakes A or B had the same period as C. For eleven of these maximum for north and south motion occurred at the same time as the maximum for east and west motion; for the remaining nine earthquakes there was a difference in time for the maximum motion of two or more minutes.

No. 3.—Out of 103 earthquakes A and B have had the same period for thirty-seven earthquakes; for the remainder they had different periods. Taking these *en bloc*, A and B have recorded maximum swing at the same time in fifty-one cases; in the remaining fifty-two cases the times for this movement have differed by two or more minutes.

No. 4.—Pendulum C (north-south motion) indicates a maximum motion very frequently before a maximum motion is recorded by A and B.

I do not see that the district from which an earthquake originates has any relationship to the pendulum which first records its apparent maximum motion.

VIII. *The Number of Earthquake Records obtained at British Stations.*

In the 'British Association Report,' 1901, pp. 44-50; 1902, p. 73; and 1903, p. 82, references are made to the number of records obtained at

Bidston, Shide, Kew, and Edinburgh. These stations are respectively situated on sandstone, chalk, alluvium, and volcanic rock. In the following table we reproduce records of frequency as given in the Report for 1902 and 1903, together with records for 1908:—

Year	Bidston	Shide	Kew	Edinburgh
1901 (11 months) . .	133	107	73	94
1901, 1902 . . .	228	168	127	155
1908	105	114	49	44

We may add that in 1908 Paisley recorded forty-eight shocks—*i.e.*, its number of records closely accorded with those obtained at Kew and Edinburgh. The subsoil at Paisley is clay (' B.A. Report,' 1905, p. 89).

At all these stations similar horizontal Milne pendulums are in use, but the adjustment of these have from time to time only been approximately similar. In 1908 at Shide 1 mm. displacement of the outer end of the boom corresponded to a tilt of $0''{\cdot}44$. The corresponding values at Kew, Bidston, and Edinburgh were $0''{\cdot}56$, $0''{\cdot}53$, and $0''{\cdot}53$, or $0''{\cdot}54$. The table shows that the Shide instrument, with the greatest sensitiveness in 1908, gave the greatest number of records. The difference between it and Bidston, however, is only nine. If we consider the latter half of 1908 only, we find that Bidston had sixty-one records and Shide had fifty-seven—*i.e.*, the result is reversed. In 1901 and 1902, when the Bidston instrument had for twelve months greater sensitiveness than the one at Shide, the number of records at the former place greatly exceeded that at the latter.

The very marked difference in the number of records obtained at Bidston and Kew, Edinburgh and Paisley, does not seem to depend upon differences in sensitiveness of the instrument, inasmuch as these differences are very slight. If we except Edinburgh and Bidston, which are founded on hard rock, there is a great difference between this and the softer materials which act as foundations for other stations.

IX. *Luminous Effects obtained from Rock Surfaces.*

In the ' British Association Report ' for 1907, pp. 87-91, a long series of experiments are described which apparently show that from time to time surfaces of chalk and killas affect a photographic surface in the same way it is affected when exposed to light. Several control experiments are described, and the conclusion arrived at was that the markings on the photographic films were not due to radio-activity, but they might be due to a very feeble brush or glowlike electrical discharge. Since the publication of the above an attempt has been made to determine whether micro-organisms play any part in the phenomena observed. With the assistance of my friend, Dr. R. C. Brown, M.D., of Parkhurst, cultures were made from scrapings from the surface of the chalk, in front of which the cylinder, covered with bromide, had been placed. This was underground. Cultures were also made from scrapings taken from the chalk outside. Micro-organisms were found in both. These have been exposed to a moving photographic surface similar to that used in the pit, but they gave no evidence of luminosity. Dr. M. H. Gordon, M.D., suggests that before excluding a biological factor special media should be tried. This we hope to do.

X. *A Catalogue of Destructive Earthquakes.*

(Still in preparation; see 'B.A. Report,' 1908, p. 78.)

During the last twelve months, as opportunity presented itself, additions have been made to a catalogue of destructive earthquakes commenced in 1907. Very many entries have been made from 'I Terremoti d'Italia,' by Mario Barata. The catalogues of C. W. C. Fuchs published in the 'Mineralogische und Petrographische Mitteilungen' have been an assistance in extending those of Alex. Perrey; while translations from Tung-Hwa-Lu, by Professor E. H. Parker (see p. 62), have extended the catalogue of Chinese earthquakes contained in the 'British Association Report,' 1908, p. 82. With these additions the compilation is at present represented by about 250 typed folios.

One result towards which its analysis points relates to the synchronism of seismic activity (see p. 56).

With the expectation of finding much material which might be used in this catalogue, I wrote to Comte F. de Montessus de Ballore, at the present time in Chile, asking whether it would be permissible to use his compilation of earthquake registers now stored at the Société de Géographie, 184 Boulevard Saint-Germain, Paris. He most willingly put this at my disposition. The catalogue is composed of about six hundred parts, which are in MSS. and in the language of the country to which they refer. They occupy a length of 26 metres of bookshelves, and for the convenience of those who wish to make researches a catalogue is provided. I understand from Comte Montessus that a number of destructive earthquakes which are recorded are but little known and difficult of access. Dr. F. Du Bois, who takes a practical interest in seismology, suggests that when using the Montessus catalogue it may often be necessary for the particular purpose in view to seek for details in the original works on which it is founded. The following are a few examples of the entries:—

1597, July 23, Perth and other parts of Scotland, Thompson's 'Annals of Philosophy,' vol. viii. p. 365; Mallet, 1852, p. 66.

1845, August 7, 14h. 15m., A. Comrie (Ecosse), 1 secousse violente; MacFarlane; Perrey Cat. 1845-46, p. 407, 13h. 15m., &c.

1880, November 28, 17h. 30m., Scotland Proc. Roy. Soc. Edinb. XI., pp. 176-187, followed by observations . . . at different places. Remarks extend over twelve pages of MS.

XI. *Developing, Fixing, and Copying a Film.*

The developer is made up as follows:—

Metol-hydroquinone Developer.

Metol	30 grains	or 7·0 grammes.
Hydroquinone . .	60 ,,	,, 14·0 ,,
Sodium Sulphite (cryst.)	1 oz.	,, 100·0 ,,
Sodium Carbonate (cryst.)	1 ,,	,, 100·0 ,,
Water	20 ,,	,, 2000 c.c.

For use, dilute with an equal volume of water.

The bromide paper after removal from the drum is rolled up film side inwards. A small quantity of dilute developer is put into a half-plate dish, then commence to unroll the film in the dish and at the same

time roll up the portion that has passed through the developer. Repeat this rolling and unrolling until development is complete. It is then transferred to a solution of hyposulphite of soda (1 hypo to 4 water) for about ten to fifteen minutes. The record is then washed, &c.

Any particular portion of a film may be reproduced by photographic printing. For the latter process place the film with its back on a piece of glass or the glass face of a printing frame. A piece of bromide paper is placed with its sensitive surface in contact with the film, and over this a strip of wood or the back of the printing frame, when the whole four are clamped together with spring clips.

This is held up to the light of an oil lamp or an ordinary gas-burner at a distance of 18 inches for about 10 seconds. Next it is developed in a little fresh but dilute developer. If the developer appears too strong, add water and a few drops of a 10-per-cent. solution of bromide of potassium. Too long exposure causes the parts which should be white to become grey. A weak acid bath (citric acid 1 part in 40 of water) tends to remove stains. In warm climates a saturated alum bath may be used. If blisters appear, weaken the hypo-bath.

XII. *Catalogue of Chinese Earthquakes*, A.D. 1638-1891. By Professor E. H. Parker.

The facts contained in the following Register are extracted, and in most cases are word for word translations, from the 'Tung-Hwa-Lu,' a well-known work which gives textually an account of most of the important disasters, prodigies, decrees, and memorials, &c., as news arrives day by day at the Peking Court of the reigning Manchu Dynasty. The list may be regarded as a continuation of the catalogue published in the Reports of the British Association for 1908. Neither of these lists is to be looked upon as complete, but if it were possible to refer to the local records of the various provincial cities each list might be considerably extended. The rendering of Chinese names follows pretty closely the system of Sir Thomas Wade, but without such extreme localisms (*e.g.*, *hsi*, *hü*, *chi*, *chü*, instead of *si*, *hi*, *tsi*, *tsü*, *ki*, *kü*) as would render these groups of initials, whether used alone or followed by a nasal final, unintelligible to persons only conversant with more southerly dialects.

Mr. Parker supplies only Chinese dates, but these have been replaced by English dates, and, it is hoped, correctly.

Catalogue.

1639	Jan. 4.	'Earthquake' (evidently in the Mukden region).
1643	Mar. 24.	'Earthquake from N.W. corner to S.E. with sound' (evidently S. Manchuria–N. Corea region).
1643	Nov. 12.	'Earthquake between 9 and 11 A.M. from N.W. to S. with sound' (evidently in S. Manchuria region).
1644	April 14.	'Earthquake at Mukden.'
1644	April 16.	'Again quaked' (*i.e.*, two days later; evidently Mukden).
1649	Nov. 10.	'Earthquake at the Metropolis' (evidently Peking, probably end of December).
1652–3		Ditto (probably end of January or beginning of February, 1653, the ninth year of the reign covering the greater part of 1652).
1653–4	'Relief,'	'When his Majesty returned to the Palace: this night there was an earthquake with sound' (probably January 1654. I cannot think why 'relief' or 'alms' should precede statement).

1654	June 6.	'Earthquake at the Metropolis' (*i.e.*, Peking).
1654	July 21.	'There were earthquakes at the Fu (cities) of Si-an, Yen-an, P'ing-liang, K'ing-yang, and Han-chung in Shen Si' (province; possibly this means 'we *heard* this day at Peking about it').
1654	between Sept. 10 and 15.	'Earthquake with sound, at the *hien* (cities) of Kwan-ch'eng, Fan, Ch'ao-ch'eng, Yang-kuh, and at the *chou* (city of) P'uh in Shan Tung (province of).'
1655	June 9.	'Exemption of the fixed taxes granted to the five Shen Si, *fu* of Yen-an, &c. (see above) on account of damage done by the earthquake.'
1655	June 22.	'Earthquake with sound at Ling-k'iu *hien* in Shan Si' (province).
1656	Aug. 1.	'Earthquake with sound at Kü-*chou* in Shan Tung (province).'
1657	Mar. 2.	'Earthquake at Yün-chên in Shan Si (province), with sound.'
1657	June 11.	'Big earthquake at the two *chou* of Wei and Mao belonging to the *fu* of Pao-ning in Sz-ch'wan (province).'
1665	April 16.	'Noon (*i.e.*, 11–1), earthquake with noise at the Metropolis.'
1668	June 11.	'Earthquake at the Metropolis.'
1669	Sept. 27.	'Earthquake at the Metropolis with noise.'
1673	Oct. 18.	Ditto.
1679	Aug. 11 or 22.	'Earthquake at the Metropolis; commands to the Ministers, &c., to examine their consciences, as also the provincial high authorities, &c., stating what they may consider to be defects, or the reverse, in Government.'
1679	Oct. 11.	'His Majesty, on account of the earthquake, goes at the head of his princes and ministers to pray at the Altar of Heaven' (outside gates, where British troops encamped, 1900).
1682	Oct. 10.	'Earthquake at the Metropolis.'
1687	Oct. 17.	Ditto.
1688	Oct. 3.	'Earthquakes at places in Hoh-k'ing and Kien-ch'uan in Yün Nan. His Majesty orders quick relief in rice and money to be sent.'
1692	June 12.	'Kalends. The President, Ma Ta'i, charged with the duty of conveying relief to P'ing-yang, &c., in Shan Si, asks instructions. His Majesty orders: "You may command Governor Galdu in view of the fact that houses have been destroyed by an earthquake, and people crushed to death, that he ought personally to have repaired to the places concerned and established a compound for residences in succour of the people who are victims to the disaster, awaiting my further orders. Instead of that he takes upon himself to go back to his capital—an exceedingly improper proceeding. Apart from what Galdu says in his own report, you must make careful inquiry and compare notes yourself, distributing our gracious relief. The land tax for this year will not be collected there at present. When you get there, at once issue a proclamation explaining to the people how deeply his Majesty the Emperor feels for them, and stating that he has specially sent a high officer to relieve them; also that they must not foolishly think of migrating and thus losing their homes. Further, as evil-disposed persons and the Brigadier's troops may take advantage of the earthquake to rob and harass the people under this or that pretext, you must order the Brigadier-General, Chou Fu-hing, to proceed in person with the Government troops under his command to take good precautionary measures in the whole region concerned. As to the victims of the disaster in Hung-tung *hien* under P'ing-yang *fu*, you must go thither in person in company with the Governor Galdu, and administer relief, seeing that all share in *bonâ-fide* kindness."'
1696	Jan. 21.	'In view of the (last mentioned) Shan Si P'ing-yang *fu* earthquake, the following manifesto to the Empire is given out:— (A long philosophical discussion on 'destiny,' &c., and relief from land tax, &c.)
1696	Feb. 3.	'Slight earthquake at the Metropolis.'
1696	Oct. 23.	Ditto.
1696	Dec. 10.	Ditto.
1697	Dec. 29.	Ditto.

1700	Mar. 12.	'Earthquake at the capital of Kwei Chow (province).
1702	Dec. 7.	'Slight earthquake at the Metropolis.'
1705	Oct. 19.	Ditto.
1706	March 24.	Ditto.
1713	Aug. 13.	'Earthquakes at Mao *chou* and at the P'ing-fan Camp in Sz-Ch'wan. Relief distributed.'
1718	July 31.	'Earthquakes at places belonging to the *fu* (cities) of P'ing-liang and Kung-ch'ang in Shen Si. Two high officers (named) sent to distribute relief.'
1718	Sept. 22.	'Emperor alludes to (? same) earthquake in Chwang-liang and other places, and lets off the land taxes, &c., for next year in Shen Si and Kan Suh provinces.'
1720	July 25.	'Emperor says that having heard of the earthquakes at Pao-an (*fu* in Chih Li) Hwai-lai (N.W. of Peking), &c., he now sends high officer (named) to these parts to examine with a view to relief.'
1721	Jan. 14.	'Alludes in decree to last year's earthquake in Shen Si province, and damage to people; also to this year's earthquake at Sha-ch'êng (N. of Peking, where commissioners sent as above), and even slight earthquakes at Peking.'
1730	Oct. 12.	'On account of the earthquake, the soldiers of the eight banner corps were given 30,000 ounces of silver each banner for house repairs, and each banner detachment in the Yüan-ming-yüan (park N.W. of Peking) 1,000 ounces.'
1730	Oct. 23.	'Half a year's extra official salary given to various other officials' (on the same ground as the above).
1730	Nov. 15.	('Long heart-searching decree. Theory of Heaven's warning, &c. Emperor did not feel it because he happened to be in a boat. Evidently protected by Heaven. The earth is still ill at ease. "My late Father" used to say small shocks always followed a big shock. In 1679 (18th K H.) the shocks lasted over a month, and history says that in 1465–1487 the shocks lasted 23 days. We must *all* try to be good, I showing example.')
1738	Dec. 13.	(Possibly Jan. 1739.) The Tartar General of Ning-hia (in Kan Suh) reports an earthquake, and that water rushes in the New Cut (a well-known ancient irrigation canal); the *hien* city of Pao-fêng has sunk away. Two hundred thousand taels given in relief from the Lan-chou (provincial capital) treasury, and a high officer despatched from Peking to superintend relief operations.
1739	April 13.	'The above-mentioned high officer reports that the New Cut and Pao-fêng belonging to Ning-hia (*fu*) have become a vast icy marsh, and that it is not possible to build thereon in the old style. He suggests that the two *hien* (cities) be abolished (∴ at that time there was also a "New Cut *hien*"), and that liberal relief be administered. Approved.' (Pao-fêng also no longer exists there.)
1744		(Seems to have been an earthquake, but my notes are defective.—E. H. P.).
1746	July 30.	'Slight earthquake at the Metropolis. Orders issued for corrective advice.'
1755	April 17.	'Orders given that extra liberal relief be administered to the families crushed during the earthquake last year in the two districts of Yih-mên (*hien*) and another *chou* (not mentioned by name) in Yün Nan (province).'
1764	Jan. 1 ?	'Earthquake in the five *chou* and *hien* districts of Kiang-ch'wan, &c.' (presumably Yün Nan).
1765	April 4 ?	'Earthquake at Tih-tao *chou* in Kan Suh.'
1765	June 7.	'Slight earthquake at the Metropolis.'
1765	Aug. 6.	'Earthquakes (? when) at the twelve *chou* and *hien* districts of Lung-si, &c., in Kan Suh.'
1785	May 30.	'Earthquake at the Hwei-hwei township and the Peh-yang Ho (River [? or township]) belonging to Suh *chou* and Yüh-mên *hien*.'
1786	Aug. 7 ?	'Earthquake at Ili' (near Kuldja).

1815	Nov. 11.	'Earthquakes at places belonging to Shen *chou* and other places in Ho Nan (province). Fang Shou-ch'ou (? the Governor) ordered to show his sympathy.'
1820	Sept.	'During this month relief was administered *re* the earthquake damage done in Hü *chou* of Ho Nan (province).'
1823[1]	Feb.	'During this month relief to (&c., &c., and) *re* the earthquake in seventeen *chou* and *hien* districts, Tsing-ning, &c., of Kan Suh (province).'
1831[1]	May.	'During this month grace granted to the land-tax payments due from three *chou* and *hien* districts of Ts'z *chou*, &c., in Chih Li, and the *hien* of Ngan-yang and Lin-chang in Ho Nan *re* damage done by earthquakes.'
1839[1]	June.	'During this month relief on account of earthquake damage to the two *chou* and *hien* districts of Lang-k'iung and Têng-ch'wan in Yün Nan, besides grace *re* payment of this year's taxes.'
1842	Aug. (probably).	'During this month relief to (&c., &c., and) Barkul on the High Road West, on account of earthquake damage.'
1849	Mar. 28.	'Liu Yün-k'o (? Governor of Fuh Kien or ? *taotai* of Formosa) ordered to institute inquiry and administer relief *re* the damage done by flooding (? tidal wave) and earthquake in the various *t'ing* and *hien* (sub-prefectures and districts) in the Northern parts of Formosa.'
1850[2]	Oct. 16.	Long decree *re* great earthquake on the 17th day of the 8th month within the walls of Si-ch'ang *hien* city in Sz-Ch'wan province. Public buildings, prisons, &c., all down. Many people crushed to death, including two Mandarins. Viceroy ordered to despatch a virtuous man to make inquiry and give relief. (Fund indicated.)
1850	Nov. 28.	Decree. Sü Tsêh-ch'ên (the Viceroy) reports all public buildings down, and over 20,600 persons of both sexes crushed to death. 'It is all my fault as Lord of the World. Let the Viceroy make strict inquiry, &c., &c.'
1852[3]	Aug. 17.	Long decree *re* great earthquake on the 8th day of the 4th moon in the city of Chung-wei *hien* of Kan Suh. There were continuous successive shocks up to the 23rd day. The Viceroy reports over 20,000 dwellings destroyed, and over 300 killed of both sexes, besides over 400 injured. Most of the public buildings down, and much of the people's food, clothing, domestic animals, &c., crushed out of sight, so that there is great destitution. Orders for inquiry, relief, &c., &c.
1852	Nov. 13.	Decree *re* Chung-wei earthquake. Emperor feels it. Viceroy's report received. 'Let him act in accordance with my sympathetic feelings, &c.'
1859	Dec. 2.	Relief (? sent) to the injured and distressed people who have suffered from the earthquake at Kai-chou and New-chwang in Fêng-t'ien (S. Manchuria).
1870[4]	June 8.	Decree. 'Then, again, Wu T'ang (Viceroy of Sz Ch'wan) represents that there has been an earthquake at Bathang, and that he is taking relief measures, &c. During the earthquake which took place this year during the 3rd moon, at and around Bathang, the flames shot forth, and numbers of the people's dwellings were crushed and destroyed. That the place in question should have suffered this disaster, indeed gives him pain,' &c., &c. (Relief steps.)
1872[5]		Earthquake in Shanghai (? summer).
1891[5]		Long description of the great earthquake in Japan.

[1] These are the *probable* months.
[2] '17th day of 8th month' = September 22.
[3] The earthquake was probably on May 28.
[4] The earthquake was probably in April.
[5] These last two taken from Mr. Parker's private notes.

Establishing a Solar Observatory in Australia.—Report of the Committee, consisting of Sir DAVID GILL (*Chairman*), Dr. W. G. DUFFIELD (*Secretary*), Dr. W. J. S. LOCKYER, Mr. F. MCCLEAN, *and* Professors A. SCHUSTER *and* H. H. TURNER, *appointed to aid the work of Establishing a Solar Observatory in Australia.*

THE Secretary is at present in Australia endeavouring to obtain the necessary funds to enable a Solar Observatory to be erected.

At the Brisbane Meeting of the Australasian Association for the Advancement of Science the following resolution was passed by the Council appreciative of the support of the British Association:—

'That in view of the generous attitude of the British Association in granting 50*l*. towards the establishment of the Observatory a similar sum be granted by the Australasian Association.'

It was quickly discovered that solar observations could not be well made at any of the existing State Observatories, and so an attempt is being made to establish a special observatory for the work, which shall be affiliated with all the Universities in the Commonwealth. For this purpose the Australian Solar Physics Committee of the Australasian Association has been formed, consisting of the Professors of Physics of each University and the Government Astronomer of each State, Mr. G. H. Knibbs, Commonwealth Statistician, being President, and Dr. Duffield, Hon. Secretary.

This Committee formed a deputation which waited upon the Commonwealth Government (Fisher Ministry) and asked for funds. The Minister replied that 'he thought Parliament would not be less public-spirited than private citizens, and would probably give pound for pound to the erection and equipment fund, and might maintain the observatory after its establishment.' The Fisher Government went out of office before the official reply was received, but the Deakin Ministry is now considering the matter and a reply is expected in the course of a few weeks.

The Australian Solar Physics Committee has written to the British Association Committee offering to undertake the responsibility of spending the grant-in-aid of 50*l*., which it is proposed to devote towards finding a suitable site for the proposed observatory.

The enclosed memorandum has been prepared for the benefit of the Federal Government by the Australian Solar Physics Committee, setting forth the aims of the proposed Observatory, the history of the movement, and the support that has been accorded. Up to the present time 950*l*. has been promised towards the equipment of the Observatory, in addition to the 'Farnham' Telescope 6-inch Grubb Refractor, and the 'Oddie' Bequest of a 26-inch Reflector and a 9-inch Grubb Refractor.

The Government have been asked to give 10,000*l*. towards the equipment and erection, and 1,500*l*. per annum for maintenance.

Solar Research.—The proposed Australian Solar Observatory.

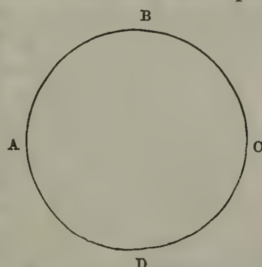
That this work is of national importance is shown by the attendance at the last Congress of the International Solar Research Union of

representatives from the observatories and scientific bodies of Austria, Belgium, France, Germany, Great Britain, Holland, Hungary, India, Italy, Russia, Servia, Spain, Switzerland, and the United States.

Australia is not represented upon the International Committee, though her co-operation is earnestly desired for the following reasons:—

The Establishment of a Solar Observatory in Australia is essential for the completion of the International Scheme.

(*a*) *Because it would fill a gap at present existing in the chain of Observatories round the Earth.*—The existence of the International Union for Solar Research is due to the fact that several problems connected with the sun depend for their solution upon a continuous series of observations made through the twenty-four hours, during which period the earth rotates once about her axis, and presents different parts of her surface in succession to the sun. It has thus passed out of the scope of two or even three stations to deal with such questions; what are required are Observatories spaced regularly round the earth so that the sun may be observed at one of them when observations are unfavourable or impossible at the others. At present the stations are concentrated in three well-defined areas, which are marked A, B, C in the sketch, and which are separated by approximately 90° of longitude. The great gap between India and America, at D, could be filled by an Australian Observatory, whose erection would enable the changes in the form of sun-spots, their numbers and areas, and the variations in the prominences and in the distribution of metallic vapours over the solar disc to be kept under continual observation throughout the whole twenty-four hours.



The circle represents the Equator.
A—India.
B—England, France, Germany, Russia, &c.
C—America (Mt. Wilson, Washington, &c.)
D—Australia.

(*b*) *Because a Solar Observatory is required South of the Equator.*—If we neglect Mauritius, where solar work is confined to direct photographs of the sun's disc, no station south of the Equator contributes towards the International Scheme, though work with the spectroheliograph is required in south latitudes, and that most important branch of study—solar radiation—must eventually be undertaken in the same part of the world. For this work a fully-equipped observatory exists at Washington, and though the Smithsonian Institution has repeatedly urged the necessity of an additional station in south latitudes, and has pointed out the benefits that may reasonably be expected from a full study of this subject, the problem is not attacked elsewhere.

(*c*) *Because Australia's Climatic Conditions are uniquely Favourable.*—With her almost perpetual sunshine Australia is particularly suitable for this work, and besides the promise that her clear skies give of excellent photographic results, the feature that makes Australian co-operation especially desirable is that observations would be possible

in Australia at the time of year when they can be least successfully made at other great observatories—Kodaikanal (India), Mt. Wilson (U.S.A.), South Kensington, &c. At the first of these the rainy season lasts from November till February, at the second from December till May, and at South Kensington work is out of the question during the English winter; consequently an observatory in Australia, where the sunshine is practically unfailing from November till March, is essential for supplying the solar observations for this season of the year, and is necessary for the fulfilment of the scheme of international co-operation.

The comment of Sir John Eliot, K.C.I.E., F.R.S. (late Astronomer and Meteorologist to the Indian Government), when this was pointed out to him, was: 'Sir, this observatory is not only advisable, it is essential.'

Besides the above reasons, which are of International Significance, there are others which may be classified as

(*d*) *Purely Scientific Reasons.*—Apart from the educational value of astronomical research, the doctrine that all work should be relegated to the country most suitable for it requires that advantage should be taken of the unique climatic conditions of Australia, which is unrivalled in the abundance of her sunshine and the clearness of her atmosphere. Such problems as the nature and cause of sun-spots, to which the recent discovery in America of vast vortices and intense magnetic fields has added so much importance—the nature of the corona and other solar appendages, the distribution of the elements over the solar disc, the pressure of the sun's atmosphere, solar rotation, the cause of the remarkable differences between the spectra from the centre of the disc and from the limb, the connection betwen solar disturbances and terrestrial phenomena are all questions of world-wide interest, and it may be hoped that Australia will share in the task of elucidating them.

(*e*) *Practical Reasons.*—It would be to Australia's advantage to undertake the work. Much has been written about the connection between solar and terrestrial phenomena, and it is the earnest hope of solar investigators that this subject may be fully dealt with at observatories well equipped for the purpose. The Council of the Royal Society of London urges the establishment of an observatory in Australia, 'especially as the subject includes the connection between solar changes and meteorological and magnetic phenomena.' Moreover, the great work on solar radiation carried out in Washington by the Astrophysical Observatory of the Smithsonian Institution 'was deliberately undertaken in the hope of improving weather forecasts,' and it is well known that the Indian Solar Observatory was erected in the belief that it would ultimately furnish results of direct value in famine prediction, the action taken by the India Office being based upon the Famine Commission Report of 1880.

The arguments for the establishment in Australia of an observatory devoted to solar physics are summarised below:—

National Reasons.—(*a*) 'The advancement of science.' (*b*) 'The educational advantages accruing from the study of an intellectual subject.' (*c*) 'The practical advantages which meteorology may fairly

expect to gain from a proper understanding of the connection between solar and terrestrial phenomena.

International Reasons.—The necessity for Australian co-operation with other nations in solar work is exemplified under the following heads:—

(*a*) 'Australia's position in longitude would enable her to fill a gap at present existing in the chain of observatories round the earth.

(*b*) 'Australia's position in latitude. No station devoted to solar research exists south of the equator, where one is required to extend and verify the work of the Smithsonian Institution's Observatory at Washington.

(*c*) 'Australia's clinical conditions would allow investigations to be made under excellent conditions at a time of year when, on account of the rainy season, work is generally impossible at other observatories.'

History of the Movement.

In April 1907 a letter to the Adelaide papers aroused some interest in the matter, and the Premier of South Australia was asked for funds to enable the Adelaide Observatory to undertake the work. This was refused on the ground that the Observatory was about to be absorbed by the Commonwealth Government.

At the last Congress of the International Solar Research Union in Paris in May 1907, Sir Norman Lockyer proposed a resolution supporting the movement, and this was carried unanimously.

A copy of this resolution was forwarded by the Chairman of the International Union to the Colonial Office, whence it was referred to the Governor-General of Australia.

The Commonwealth Government, in the absence of an Astronomical Department, referred the matter to the Meteorological Department, which reported that 'it is very desirable that such an observatory should be established, &c.,' and inquiries were made as to the *personnel* and equipment of existing State observatories for carrying out the work. These, however, replied that they were not equipped for the purpose, and could only undertake the work if the necessary funds should be forthcoming from the Commonwealth Government.

The British Association offered its influential support, and formed a committee to co-operate with Australian astronomers in furthering the movement, Sir David Gill, K.C.B., F.R.S., being Chairman.

The Royal Society expressed its approval of the project and suggested that the proposed observatory should be affiliated with the Adelaide University. But the Council of the University, though willing to undertake the work, could only do so if the funds were forthcoming from an external source.

A broader basis for this observatory, however, lay in its being affiliated not with one university but with all the universities within the Commonwealth, the matter being one which affects the prestige of Australian science not the science of any one particular State.

Upon these lines therefore the Australian Solar Physics Committee was formed at the meeting of the Australasian Association for the Advancement of Science in Brisbane, January 1909, the members being:—

G. H. Knibbs, Esq., Commonwealth Statistician, President; W.

Geoffrey Duffield, D.Sc., Hon. Secretary; Professor Bragg, F.R.S., President of the Australasian Association; Senator Keating; the Professors of Physics of the Sydney, Melbourne, Adelaide, and Hobart Universities, which they officially represent, and the Government Astronomers of the Australian States.

This Committee formed a deputation which waited upon the Minister for Home Affairs of the Commonwealth Government (Fisher Ministry), and presented the resolution which had been passed by the Council of the Australasian Association for the Advancement of Science. The Minister replied that 'he thought Parliament would be not less public spirited than private citizens, and would probably give pound for pound to the erection and equipment fund, and might maintain the observatory after its establishment.'

Scientific Institutions supporting the Proposal.

The International Solar Research Union.—At the meeting in Paris, May 1907, the following resolution was proposed by Sir Norman Lockyer and carried unanimously: 'That this International Congress hears with great satisfaction of the proposal to establish a Solar Physics Observatory in Australia, and expresses its decided opinion that an observing station in that part of the world would fill a gap which now exists in the system of observatories distributed over the earth, and yield contributions of great value to the study of solar phenomena.'

The Royal Society, February 10, 1908.—'The Royal Society are strongly of opinion that the foundation and equipment of a Solar Observatory in Australia are desirable, or else, as an alternative, that provision for systematic solar observations, including an adequate staff, should be made at one of the existing observatories. They are of opinion that a very valuable contribution could thus be made by Australia to the international scheme for solar research now in operation, especially as the subject includes the connection between solar changes and meteorological and magnetic phenomena, in the systematic international observation of which Australia already takes a share.'

The British Association for the Advancement of Science, September 1908, formed a committee to co-operate with Australian astronomers 'to aid in the establishment of a Solar Observatory in Australia,' consisting of Sir David Gill, F.R.S. (Chairman), Dr. W. G. Duffield (Secretary), Professors Schuster and Turner, Dr. W. J. S. Lockyer, and Mr. F. K. McClean, and a grant-in-aid of 50*l.* was voted.

Australasian Association for the Advancement of Science, Brisbane, January 1909.—The Council passed the following resolution: 'That the Australasian Association for the Advancement of Science records its unanimous support to the movement for the establishment in Australia of an Observatory devoted to the study of solar physics, which has been so strongly advocated by the International Union for Co-operation in Solar Research, by the Royal Society, and by the British Association for the Advancement of Science, and which is essential to the scheme of solar study instituted by the International Union. The practical possibilities, combined with the scientific value of solar research, makes the project a matter of national and of international importance.' 'That a copy of the foregoing resolution be forwarded to the Prime Minister of Australia, with an urgent appeal that steps be taken to

secure the establishment of a Solar Physics Observatory in Australia.' 'That a committee be formed to aid in the work of establishing such an observatory.' 'That in view of the generous attitude of the British Association in granting 50*l*. towards the establishment of the observatory a similar sum be granted by the Australasian Association.'

Smithsonian Institution, October 31, 1907.—The Secretary writes: 'Mr. Abbot, the Director of the Astrophysical Observatory here, with whom I have conferred in the matter, is of the opinion that Australia furnishes excellent sites for a Solar Observatory because of cloudlessness. It is now known that there are rapid changes occurring on the sun, which for their proper understanding require nearly continuous observations to be made. Few existing observations are situated in regions where good solar observing conditions are common, and there is abundant opportunity for valuable work on the part of the proposed Australian Observatory. Its situation is exceptionally favourable both in latitude and longitude, and therefore the more desirable, so that it may be unhesitatingly said that an Australian Solar Observatory is likely to promote knowledge in many branches of science. While, of course, the advantage to science is a sufficient argument among scientific men for the usefulness of such an establishment, it may be fairly claimed that such an observatory would have a direct value for the people of Australia. Indeed there is no branch of astronomy which more fully deserves the support of the Government because of its probable utility, than the study of solar radiation in its relations to life and climate and power upon the earth.'

In addition to the above institutions and to British and Colonial observatories the project has the support of the following: 'The Mount Wilson Solar Observatory, California, U.S.A.; 'The Royal Observatory of Cetania and Etna'; and 'The Society of Italian Spectroscopists.'

The Present State of our Knowledge of the Upper Atmosphere as obtained by the use of Kites, Balloons, and Pilot Balloons.—Report of the Committee, consisting of Messrs. E. GOLD *and* W. A. HARWOOD.

[PLATE II.]

CONTENTS.

I. INTRODUCTORY.

THE past decade has been most fruitful in the application of self-recording instruments to the investigation of the free atmosphere. But the work has been mainly confined to obtaining, collecting, and publishing the

results of the observations. The results obtained from manned balloons were arranged and discussed very fully and systematically ten years ago by the German meteorologists, Von Bezold, Assmann, Berson, and Süring;[1] but the discussion of the much more numerous results obtained with kites and registering balloons has been devoted to isolated ascents or to special points, frequently imperfectly treated owing to the gaps and to the difficulty of dealing single-handed with a mass of undigested material. At the same time very much valuable knowledge has been acquired, and the meteorologist of to-day is in consequence much better equipped in many respects for attacking the problems to which his predecessors could bring only the ingenuity of speculation and of theory, although his work may be more difficult and less entertaining than theirs.

By the use of kites a fairly complete knowledge has been obtained of the variation in the meteorological elements up to a height of 2 km. Registering balloons have furnished information regarding the distribution of temperature up to a height of 15–20 km. But the comparative absence of arrangement of the observations in a form suitable for discussion has necessitated a considerable amount of labour in extracting from the observations the information they contained. It has therefore been impossible to deal with all the branches of investigation, and the discussion of the observations of humidity, of the constitution and formation of clouds and fogs, and of the electrical state of the free atmosphere has not been included. The Report deals with the instruments and the methods of investigation and with the results for temperature and for wind.

II. *Historical Summary.*

Free Manned Balloons.[2]—The scientific investigation of the conditions of the upper atmosphere was begun about the middle of the eighteenth century by Bouguer, a French Academician, during a geodetic expedition to Peru. He fixed the height of the freezing-point in various latitudes by means of observations on the slopes of mountains. The first scientific manned balloon ascent was made by Jeffries, November 30, 1784, from London. The balloon-car contained a thermometer, barometer, hygrometer, electrometer, mariner's compass, and bottles filled with water for obtaining samples of air. The rate of fall of temperature was found to be 1° F. per 360 feet. No change of electrical conditions was indicated. Samples of air were sent to the Royal Society, but were apparently not analysed ; a paper on the results was read before the Society, January 1786. The observations of Jeffries compare favourably with those made until the adoption of aspirated instruments. Some time then elapsed before the next ascent for purely scientific purposes was made. In 1803–04 Robertson, a Belgian physicist, made three ascents from Hamburg and St. Petersburg. The third was made under the auspices of the Russian Academy, which proposed to examine the change in the rate of evaporation of fluids, change of magnetic force and magnetic inclination, and the increase of solar heat with increase of height. The Paris Academy of Sciences took up the investigation in the same year, and Biot and Gay-Lussac together (August 24, 1804), and later Gay-Lussac alone (September 16, 1804), made ascents from Paris to verify Robertson's St. Petersburg results, which indicated that the magnetic force diminished with

[1] *Wissenschaftliche Luftfahrten*, 1899.

[2] A good general account of the ascents made before 1870 is given in *Travels in the Air*, by Glaisher, Flammarion, de Fonvielle, and Tissandier.

increase of height. Gay-Lussac found the rate of fall of temperature to be 1° F. per 300 feet and that the magnetic force increased with height. No further investigation was made until 1850, when Messrs. Barral and Bixio made two remarkable ascents from Paris. They demonstrated the great thickness (about 15,000 feet) of some cloud masses and noted that while the light from the sky was polarised, that reflected from the clouds was not. At 23,000 feet they encountered a cloud consisting of ice particles.[1] The British Association first took part in the work in 1852, when Mr. John Welsh made four ascents from the Kew Observatory. The object of the ascents was to find the rate of diminution of temperature and change of humidity, to collect samples of air, and to examine the light from the clouds for polarisation.[2] Recognising the probable effect of the sun on exposed thermometers, Welsh enclosed his thermometers in a polished metal tube through which air was forced by bellows, thus instituting the aspirated apparatus perfected later by Dr. R. Assmann of Berlin. The thermometers were very sensitive, falling through 20° F. in 11 seconds on being taken from a warm to a cold room. He attained heights ranging from 4 to 7 km., and found that the temperature fell uniformly, until at a certain height, which varied on different days, the fall was arrested and the temperature remained practically constant through 600 to 900 metres. The uniform diminution was then resumed, but at a less rapid rate. The seasonal variation of the rate of fall of temperature was demonstrated. It was found that the light reflected from clouds was unpolarised.[3]

The experiments in connection with the British Association were continued by a Committee appointed at the Manchester meeting in 1861. The experimental work was undertaken by Mr. Glaisher, who with Mr. Coxwell made twenty-eight ascents during the period July 17, 1862, to May 1866.[4] The chief objects of the investigation were to find the laws of variation of temperature and humidity with height, and to examine the variation of magnetic force and electric potential.

Glaisher at first employed Welsh's aspirated thermometers, but noticing that these recorded the same values as the exposed instruments he discontinued the aspiration. Subsequent observations have shown that the agreement between the indications of aspirated and unaspirated instruments was due to faulty exposure in the balloon-car. He took also maximum and minimum thermometers, ozone papers, and an electrometer lent by Professor W. Thomson of Glasgow (Lord Kelvin).

As the number of observations increased the conclusions drawn became more uncertain. To quote Glaisher's words :—

'It was found that those taken in the morning hours did not accord with those taken in the afternoon hours, nor did those taken at one time of the year agree with those taken at other times of the year.'[5]

In cloudy weather the rate of fall was 1° F. per 300 feet, but in clear weather 1° F. per 160 feet at first, and only 1° F. per 1,000 feet at 6 miles. Observations at night were made with the help of miners' lamps, when it was found that the temperature rose as the height increased. The results for humidity were similar to those of Welsh. At a height of five miles (8 km.) there was almost complete absence of water vapour. The time of vibration of a suspended magnet was found to diminish with increase

[1] *Nature*, xviii. p. 639.
[2] *Brit. Assoc. Reports*, 1852, p. xxix.
[3] *Phil. Trans.*, 1853.
[4] *Brit. Assoc. Reports*, 1861–66.
[5] *Brit. Assoc. Reports*, 1862, pp. 31, 376; 1863, p. 426; 1864, p. 195; 1865, p. 145; 1866, p. 367.

of height: a result contrary to that of Gay-Lussac, but in agreement with that of Robertson.

In 1869 Glaisher made further observations to examine more closely the variation of temperature and humidity up to 1,000 feet. These later observations were the first obtained by means of a captive balloon. They indicated a decided diurnal range of temperature.[1] The work was not pursued further in England, but interest was stimulated in France, and many ascents were made by MM. Flammarion, de Fonvielle, and Tissandier. In 1875 two ascents were made by Tissandier, Crocé-Spinelli, and Sivel, one of long duration (24 hours) and the other to a great height (9,000 metres). The apparatus carried included a pump to draw air through tubes filled with potash for estimating the amount of carbon dioxide, a spectroscope for examining the water-vapour line in the solar spectrum, two aneroid barometers, one giving the pressure from 0 to 4,000 m. and the other from 4,000 m. to 10,000 m., two barometric tubes for registering the lowest pressure, and thermometers.[2] This ascent resulted in the death by suffocation of Crocé-Spinelli and Sivel, and in consequence only one ascent was made in France between 1875 and 1878. The successful construction of the large Giffard captive balloon in Paris in 1878 gave a great impetus to aeronautical work in France.[3] In 1879 the Paris Academy inaugurated its first series of ascents, and Tissandier made observations to verify the barometer height formulæ by means of photographs from the car, a method originally proposed by Le Verrier in 1874.[4] In the same year (1879) the International Congress of Meteorologists at Rome passed several resolutions relating to the importance of balloon observations in meteorological investigation.[5] In July 1881 MM. W. de Fonvielle and Lippmann made an ascent after midnight, carrying only barometer and thermometer,[6] and about the same time the investigation was resumed in England by the Meteorological Office.[7]

The number of balloon ascents accomplished and the observations made had now become very numerous and widely distributed, but it was seen that the results were strangely discordant. No organised balloon ascents had taken place in Germany, though isolated ascents had been made since about 1880; but German meteorologists attributed the discrepancies to faulty instruments and methods of observation. Comparisons by A. L. Rotch in ascents from Paris and Berlin showed that Richard's self-recording thermometer registered 8° C. higher than a sling thermometer, and the latter 2° higher than a new aspirated thermometer designed by Assmann in 1887.[8] These tests showed the necessity for the use of accurately specified methods of observation and thoroughly tested instruments in all countries. The doubt thrown on all previous observations caused the Prussian Meteorological Institute to inaugurate a series of experiments to repeat the work of Glaisher. Forty-seven ascents were made between June 1888 and February 1895. In these ascents the instruments were placed in a well-ventilated enclosure and their indications were compared with those of instruments exposed as in earlier ascents. In four cases self-recording instruments were used. On December 4, 1894, Dr. A. Berson rose to a height of 9,600 m., the highest level at

[1] 'On the Changes of Temperature and Humidity of the Air up to 1,000 feet,' J. Glaisher, *Brit. Assoc. Reports*, 1869.

[2] *Compt. rend.*, 1875, pp. 803, 866, 976, 1060.

[3] *Nature*, vol. xviii. p. 291.

[4] *Ibid.*, vol. xlviii. p. 160.

[5] *Ibid.*, vol. xx. p. 58.

[6] *Ibid.*, vol. xxiv. 225.

[7] *Ibid.*, vol. xxv. p. 158.

[8] *Ibid.*, vol. xlv. p. 168; vol. xliv. p. 512.

which observations had been made,[1] and later (in 1901) Berson and Süring rose to 10,800 m.[2] On the latter occasion both aeronauts were unconscious at the maximum height, and revived only after the balloon had descended about 4,000 m. In Glaisher's famous ascent from Wolverhampton, September 5, 1862, the last observation was made at 8,900 m., although the balloon was supposed subsequently to have risen 2,000 m. higher.[3] Special precautions were taken to make the two series of ascents comparable, Berson going so far as to make an ascent from the Crystal Palace in September 1898, a simultaneous ascent being made from Berlin. The final results showed that Glaisher's results for temperature were faulty, the error probably arising through insufficient ventilation. In the ascent of December 1894 the temperature at the maximum height was −54° C. by the aspirated thermometer and −11° C. by the exposed thermometer. The results, together with those of Berson and Süring, and of a simultaneous ballon-sonde ascent, are shown for comparison in the table [4] :—

Height, metres	Fall of Temperature ° C. per 1,000 metres			
	Glaisher	Berson	July 31, 1901 Berson & Süring	July 31, 1901 Ballon-sonde
0–1,000	7·5	5·0	7·2	8·3
1,000–2,000	6·5	5·0	6·8	6·1
2,000–3,000	5·0	5·4	3·7	4·2
3,000–4,000	4·2	5·3	5·2	5·1
4,000–5,000	3·8	6·4	7·4	5·7
5,000–6,000	3·2	6·9	5·5	6·3
6,000–7,000	3·0	6·6	7·2	4·7
7,000–8,000	2·0	7·0	7·2	7·6
8,000–9,000	1·8	9·0	3·6	7·1

It will be noted that in Berson's observations there was no indication of the isothermal zone discovered by Teisserenc de Bort and Assmann.[5]

Later experiments with free manned balloons have been in most cases confined to lower altitudes and have been made principally for comparison with, and verification of, observations made by other means.

Captive Balloons.—After Glaisher's work in 1869, captive balloons were little used for scientific purposes until 1890. In 1876 Mendeléef proposed to construct a large captive balloon and to fit it with apparatus of his own design,[6] and in September 1889 tests of barometer-height formulæ were made by means of a captive balloon in Russia; but in general the shocks and jars sustained by these balloons owing to gusts of wind, together with their violent oscillations and frequent rapid rotation, rendered them extremely unsuitable for mercury barometers, while in winds of only moderate strength they refused to rise to any considerable height and drifted along close to the ground. E. D. Archibald in 1885 proposed to employ a captive kite-balloon to get rid of the captive balloon's defects, and in 1887 claimed to have obtained satisfactory results.[7] The

[1] *Nature*, vol. liii. p. 136.
[2] *Ergebnisse der Arbeiten am Aëron. Obs. Berlin*, 1900–1901, pp. 224–233.
[3] *Brit. Assoc. Reports*, 1863; *Travels in the Air*, Glaisher.
[4] *Nature*, vol. lxv. p. 224.
[5] The ballon-sonde record indicated that it was reached at 12 km.
[6] *Nature*, vol. xiv. p. 517.
[7] *Ibid.*, vol. xxxvi. p. 278.

introduction of sufficiently rigid self-recording barometers and reliable recording thermometers and hygrometers, however, rendered captive balloon observations far more practicable.[1]

The kite-balloon of Siegsfeld and Parseval, a more elaborate apparatus than that of Archibald, was first used to raise meteorological instruments in 1898 at Strassburg, and has since been used regularly at the Prussian Meteorological Institute, Lindenberg, to obtain observations in calm or nearly calm weather. At most other stations ordinary captive balloons have been used, and in weather when both kites and captive balloons are useless, small pilot balloons have been employed to determine the direction and velocity of the wind.

Pilot Balloons.—The use of small free balloons was first suggested by Le Verrier in 1874.[2] In 1877 M. Secretan of Paris, under the direction of M. W. de Fonvielle, sent up a series of small indiarubber balloons in order to investigate the changes of wind direction with altitude and to determine the heights of clouds.[3]

The method was quickly adopted in America, and before the end of 1877 it was decided to use these small pilot balloons regularly in Arctic work.[4] They were also employed in 1879 by the French Academy in preliminary ascents to determine the paths which manned balloons would take.[5]

In continuation of the investigation of the variation of wind with height, M. Bonvallet in 1891 despatched ninety-seven paper balloons from Amiens, and sixty of the cards attached to the balloons were returned. The experiments were continued by Hermite during the period 1893–1898, and about half of the balloons sent up from Paris were returned from within a radius of 100 miles.

Subsequently these pilot balloons have been employed regularly with theodolites in determining the direction and velocity of the wind at various heights, and to continue the observations when kites could not be flown owing to calm weather, or when an opposing current prevented the further rise of the kite.[6] They have, too, the advantage of reaching greater heights than kites.

Kites.—The first use of kites for scientific purposes was made by Alexander Wilson and his pupil Thomas Melville at Glasgow in 1749.[7] In these experiments thermometers were raised to considerable heights. Three years later Franklin performed his famous experiment of collecting electricity with kites.[8] In 1822–23 the Rev. George Fisher and Captain Sir Edward Parry, using self-registering thermometers, obtained temperatures by means of kites at different heights in Arctic regions.[9] Some time later, in 1840, Espy, an American meteorologist, employed kites to verify his calculations of the heights of clouds from measurements of humidity.[10] The experiments also extended to England, for W. R. Birt of the Kew Observatory flew kites in 1847 with the hope of obtaining the changes of temperature, humidity, and wind with height. In 1883–85 E. D. Archibald used kites with steel piano-wire to obtain the wind

[1] *Nature*, vol. xlv. p. 168.
[2] *Ibid.*, vol. xlviii. p. 160.
[3] *Ibid.*, vol. xv. p. 458.
[4] *Ibid.*, vol. xvii. p. 171.
[5] *Ibid.*, vol. xx. p. 401.
[6] P. 244; *Compt. rend.*, 141, pp. 605–608, October 9, 1905; 142, pp. 918–921, April 9, 1906.
[7] *Trans. Roy. Soc. Edin.*, vol. x., part ii. pp. 284–286.
[8] Sparks' *Works of Franklin*, vol. v. p. 295.
[9] Symon's *Meteorolog. Mag.*, April 1897.
[10] Espy, *Philosophy of Storms*, 1841, p. 75.

velocity, employing a Biram's anemometer, which registered the total amount of wind from beginning to end of the flight.[1]

In 1885 Alexander McAdie repeated Franklin's experiments on Blue Hill, U.S.A., using an electrometer,[2] and in 1891 and 1892 he measured the electric potential simultaneously at the base, on the slopes, and with kites above the summit of Blue Hill. About the same time L. Weber was making more extensive use of kites at Breslau, Germany, to collect electricity.[3] About 1890 Wm. A. Eddy, after making experiments with various forms of kites, devised a modified form of the Malay tailless kite, and in 1891 used several of these to raise a minimum thermometer, proposing thus to obtain additional data for weather-forecasting. The experiments were continued at the Blue Hill Observatory, and in 1894 the first continuously recording instrument was sent up.[4] Later, the weight of the instruments was reduced and more efficient kites were devised. A report on the work being carried out at Blue Hill was presented to the International Meteorological Conference at Paris, September 1896,[5] and in 1898 the International Aeronautical Committee recommended the inclusion of the kite and kite-balloon among the apparatus of all the principal observatories.[6] In the same year M. L. Teisserenc de Bort equipped a kite station at the Observatory of Trappes near Paris, and kites were used by M. Rykatcheff at St. Petersburg. In 1901 Rotch made experiments with kites flown over the sea from steamships.[7] In 1902 kite experiments were made by W. H. Dines on land and also over the sea from a small steam-vessel, on the west coast of Scotland.[8] The experiments were continued at Oxshott and subsequently at Pyrton Hill for the Meteorological Office. In the same year successful kite experiments were made by Berson and Elias in a cruise to Spitsbergen, by Köppen in the Baltic,[9] and by Fassig, for the American Weather Bureau, in the Bahamas.[10] Teisserenc de Bort extended his experiments to Scandinavia in 1902–03, and under his direction kites were flown day and night when possible at Hald in Jutland during nine months. The apparatus was then transferred to a Danish gunboat and ascents were made over the Baltic. During this cruise the highest kite ascent up to that date was made, the height recorded being 5,900 m.[11] During the autumn of 1904 Professor Hergesell made a series of ascents from the yacht of the Prince of Monaco over the Atlantic, in the neighbourhood of the Canary Islands, and the Azores.[12] These experiments were followed in 1905 by a similar expedition, organised by Teisserenc de Bort and Rotch, to the neighbourhood of Madeira, Teneriffe, and Cape Verde,[13] and the expedition was repeated in 1905 and 1906.[14] The experiments were extended at the desire of the International Committee to India in 1905, observations being made at Karachi in 1905 and subsequently at Belgaum.[15] In 1907 a similar station

[1] *Brit. Assoc. Reports*, 1884, p. 639, and 1885.

[2] *Proc. Amer. Acad. Arts and Sciences*, vol. xxi. pp. 129–134.

[3] *Electrotechnische Zeitschrift.*, November 1886 and August 1889.

[4] *Quarterly Journ. Roy. Met. Soc.*, 1897. The observatory was established and maintained by Rotch. Much of the experimental work was carried out by H. H. Clayton.

[5] *Nature*, vol. lvi. p. 602.

[6] *Ibid.*, vol. lviii. p. 380.

[7] *Ibid.*, vol. lxvii. p. 137.

[8] *Ibid.*, vol. lxvii. p. 311.

[9] *Ergeb. der Arbeit. am Aër. Obs. Lindenberg*, pp. 1–20, 1901–1902.

[10] *Nature*, vol. lxx. p. 228.

[11] *Travaux de la Station Franco Scandinave à Hald*, 1902–03, p. 40.

[12] *Compt. rend.* **140**, pp. 331–333, January 30, 1905; *ibid.*, pp. 1569–1572, June 5, 1905.

[13] *Ibid.*, **141**, pp. 605–608, October 9, 1905; **142**, pp. 918–921, April 9, 1906.

[14] *Nature*, vol. lxxiv. p. 40; lxxv. p. 211.

[15] *Ibid.*, vol. lxxviii. p. 280.

was established in Egypt,[1] and about the same time a station, at which daily ascents were to be made, was equipped at Glossop in England.[2] The upper air observations obtained at the English stations, viz., Pyrton Hill, Glossop, Ditcham Park, and Brighton, are published in the *Weekly Weather Report of the Meteorological Office.*

Ballons-Sondes.—The use of small free balloons to raise self-recording meteorological instruments was proposed in Copenhagen as far back as 1809.[3] At that time, however, no satisfactory self-recording instruments were available and the idea was not taken up. It was revived in 1873 and 1874 by Jobert and Le Verrier, who proposed in this way to test barometer-height formulæ,[4] and again by Mendeléef at the International Meteorological Congress at Rome, 1879.[5] It was not until self-recording instruments had been considerably improved, however, that satisfactory observations became possible, and Hermite in 1893 was the first to put the idea into practical form. Satisfactory ascents were made by means of a varnished paper balloon, 'L'Aérophile,' filled with coal-gas, but on the bursting of this it was resolved to construct a balloon of goldbeater's skin. With this second 'aérophile,' whose capacity was 113 cubic metres and weight 14 kgm., ten ascents were made by MM. Hermite and Besançon between 1893 and 1898.[6] In 1893 also Prof. Hazen attempted similar experiments in America.[7] The objection was raised that the results obtained in this way were subject to the same errors due to insolation as those of Glaisher in 1861–69.[8] Consequently a silk balloon, the 'Cirrus,' capacity 250 cubic metres and weight 42 kgm., was constructed and made eight ascents from Berlin between July 1894 and June 1897. All the instruments were enclosed in an aspirated tube (a 'Urania Pillar'), designed by Assmann. The highest ascent of the 'Cirrus' was made in September 1894, when the pressure fell to 50 mm. at 18,500 m. and the minimum temperature was —67° C.[9]

During the progress of the German experiments negotiations were carried on to obtain the general acceptance of uniform methods of observation and the interchange of instruments with a view to evolving the best possible type. In consequence the International Meteorological Conference at Paris, September 1896, appointed a committee, consisting of de Fonvielle, Hermite, Assmann, Erk, Hergesell, Pomortzeff, and Rotch, to organise a series of simultaneous international ascents.[10]

These ascents extended rapidly, and already in 1896 four manned and four registering balloons were sent up on the same dates from France, Germany, and Russia.[11] In 1898 the ascents were extended to Austria and Italy, in 1899 to Belgium, and in 1901 to England.

Besides the work done in connection with the International Committee, extended series of ballons-sondes ascents were undertaken independently. Between April 1898 and 1902 Teisserenc de Bort sent up 258 ballons-sondes, which attained heights of 11 km.,[12] and similar

[1] *Quart. Journ. R. Met. Soc.*, 1908, p. 259.
[2] *Brit. Assoc. Reports*, 1907.
[3] *Ann. Harvard Obs.*, lxviii. part I, p. 1; *History and Practice of Aëronautics*, John Wise, 1850.
[4] *Nature*, xlviii. p. 160; *Ann. Harvard Obs.*, lxviii. part I, p. 1.
[5] *Quart. Journ. R. Met. Soc.*, 1897.
[6] *Compt. rend.*, 1896, p. 961; 1897, pp. 424, 1180; *Acad. des Sciences*, April 15, 1896; *L'Aérophile*, vol. i., No. 1 *et seq.* 1893.
[7] *Ann. Harvard Obs.*, lxviii. part I, p. 2.
[8] *Nature*, vol. li.
[9] *Ibid.*, vol. lvi. p. 602.
[10] *Ibid.*
[11] *Ibid.*
[12] *Compt. rend.*, **129**, pp. 417–420; **141**, pp. 153–155; *Soc. Franc. Phys. Séances*, **3**, 1899, pp. 126–135.

apparatus was employed in the Atlantic expeditions of Rotch and Teisserenc de Bort, and of Hergesell in 1902–05.[1] Rotch made the first series of registering balloon ascents in America at St. Louis in 1904.[2] In 1907 the International Committee at Milan, adopting the suggestion of Teisserenc de Bort, determined to carry out the observations on a much more extended scale in the northern hemisphere. The work was extended to Africa and India, and several stations in Great Britain began to take part regularly in the ascents. Almost all the countries of Europe had previously taken part in the monthly international ascents, made since 1901 on the first Thursday in each month, and these countries continued to participate in the extended series, which included ascents of several balloons on successive days at stated periods. The results are collected and published by the International Committee. In addition, special ascents have occasionally been made, such as those at Milan during the month of September 1906 and at Manchester, June 2 and 3, 1909. On the last occasion twenty-five balloons were liberated in twenty-four hours, and during the same period four balloons were sent up at intervals of six hours from most of the Continental stations.

III. (*a*) *Apparatus and Instruments employed in ascents of Balloons and Kites.*

The increasing use of captive balloons, which were subject to sudden shocks and jars, of ballons-sondes, and of kites, gave a strong impetus to the work of designing really satisfactory self-recording instruments. The light self-recording aneroid barometers, Bourdon tube thermometers and hair hygrometers of Richards Frères, came to be considerably used with kites and ballons-sondes. They recorded through levers and metal styles on smoked paper, wrapped round a revolving clockwork drum. They were used with kites at the Blue Hill Observatory, U.S.A., alongside a meteorograph designed by Fergusson, which included also an anemometer, and by Hermite and Besançon with ballons-sondes in 1893–98. In 1891[3] Assmann described a new form of aspirated psychrometer, which was so far independent of shocks and jars as to be suitable for use with captive balloons.[4] In the following year, in a review of the results of tests and observations made in Germany by balloons and captive balloons, he stated that the aneroid barometers and aspirated thermometers which had been employed were satisfactory, the aspiration being absolutely necessary in order to obtain consistent and comparable results. The self-recording instruments used registered temperature by means of a bent Bourdon tube filled with alcohol, humidity by means of a bundle of hairs, and pressure by an aneroid barometer, the whole being enclosed in an aspirated space.[5] At the second meeting of the International Committee in 1898[6] Teisserenc de Bort exhibited a self-recording thermometer consisting of a blade of German silver fixed in a frame of Guillaume steel, which had small thermal inertia (requiring only 15 seconds to indicate a sudden change of temperature of 9° C.), and which was not affected by shocks. Cailletet showed an instrument for photographing simultaneously the face of the aneroid and the ground in order

[1] See above, p. 77.
[2] *Ann. Harvard Obs.* vol. lxviii. part 1.
[3] *Nature*, vol. xliv. p. 502.
[4] *Ibid.*
[5] *Ibid.*, vol. xlv. p. 168.
[6] *Ibid.*, vol. lviii. p. 380.

to verify barometer-height formulæ.[1] The 'dromograph' of Hermite and Besançon, a theodolite registering automatically the azimuths and angular altitudes of a balloon viewed from the ground, was also exhibited, as well as a heliometer employed by Kremser of Berlin for measuring the apparent diameter of balloons, and used since with pilot balloons.

At this meeting it was resolved that—

(1) Thermometers of less *thermal inertia* than those previously employed were necessary.
(2) Efficient ventilation was indispensable.
(3) Instruments should be tested before the ascents under circumstances similar to those encountered during the ascents.
(4) An aspiration psychrometer suspended at least five feet below the car was the only instrument suitable for manned ascents.

At the third meeting of the Committee at Berlin, May 1902,[2] Assmann showed a compact apparatus for use with ballons-sondes, weighing only 500 gm. The instrument registered through a pen filled with saltpetre on a sheet coated with lampblack which had been treated with a solution of 'Tonsol,' and the resulting red trace could not be obliterated either by handling or by immersion in water. Hergesell and Teisserenc de Bort also exhibited self-recording thermometers.

The type of instrument finally evolved for use with ballons-sondes had (1) a completely exhausted Bourdon tube barometer, which was found to show less fatigue effect than the aneroid barometer; (2) Teisserenc de Bort's bimetallic thermometer and Hergesell's German-silver tube thermometer; (3) a hair hygrometer. The working parts of the instrument were enclosed in an aspiration tube. Similar instruments were designed for use with kites.

The principal self-recording instruments which have at various times been used have been designed by Richards Frères, C. F. Marvin, Fergusson, L. Teisserenc de Bort, R. Assmann, H. Hergesell, and W. H. Dines.[3] Richards, Marvin, Hergesell, and Dines designed instruments for use with kites; and Richards, Teisserenc de Bort, Assmann, Hergesell, and Dines ballons-sondes instruments.

Kite Meteorographs.—The Richard kite meteorograph is a baro-thermo-hygro-anemograph. The barometer is a double aneroid, and the thermometer a Bourdon tube filled with alcohol. The hygrometer consists of a bundle of hairs, and the anemometer is of the Robinson cup type, operating through cogwheels and pulleys. The cups are mounted on a vertical spindle, projecting below the instrument, and thus work in an inverted position. The records are traced side by side on a smoked sheet fixed round a clockwork rotating drum, by styles connected through systems of levers to the various parts of the instrument.

The whole instrument, with the exception of the anemometer cups, is enclosed in a protecting case. Ventilation is obtained by an opening in the front of the case and perforations in the back. The instrument is kept head to wind by means of a vane. Its total weight is 1,820 gm.

The Marvin kite instrument is similar to the Richard instrument. The barometer is a large double aneroid with steel boxes. The ther-

[1] *Compt. rend.*, 125, 1897, pp. 587–589. [2] *Nature*, vol. lxvii. p. 137.
[3] A detailed account of Dines' instruments and methods is contained in *The Free Atmosphere in the Region of the British Isles*, M.O., No. 202.

mometer consists of two annular Bourdon tubes of very thin steel filled with alcohol, and the hygrometer consists of two bundles of hairs. The anemometer originally used was a small instrument of the Robinson cup pattern operating through an electro-magnet on a small hammer and recording on the drum in steps, each step corresponding to 2·8 km. of wind. The anemometer cups were originally fixed to the upper end of the kite, but later were placed on a vertical spindle above the hinder end of the vane, so as to be away from the disturbing influence of the remainder of the apparatus. The thermometer tubes and hygrometer hairs are enclosed in a polished tube open at both ends, which is kept always end on to the wind by means of the vane. The rest of the instrument is enclosed in a light protecting case. In later patterns of the instrument used at the Lindenberg Observatory, Germany, the anemometer was replaced by an Assmann anemometer. As the Robinson cups were very liable to damage in falling, Assmann's instrument was designed on the Woltmann flywheel anemometer principle. It took the form of an eight-bladed fan fitting into the end of the aspiration tube and operating through a train of cogwheels on the marking pen. The instrument, when used with the anemometer, is suspended from the wire some distance below the kite, to avoid any disturbing effect due to the latter. The weight of the instrument is about 1·06 kgm.

The Bosch-Hergesell kite meteorograph differs in having a Bourdon tube barometer and an annular Bourdon tube filled with alcohol for thermometer. The anemometer is of the Robinson type, operating through a train of cogwheels and pressing the style on the record sheet once per minute in a wind of 6 m.p.s.—*i.e.*, one contact per 360 metres of wind. The thermometer and hygrometer are enclosed in an aspiration tube, and the anemometer cups are mounted on a vertical spindle projecting through the instrument case. The protecting case is of aluminium and the frame of the instrument of magnalium. The total weight is 750 gm.

The Dines instrument is of quite different design.[1] The frame consists of a wooden tray with raised sides for protecting the instrument from injury. In the middle of the frame a flat circular disc of white cardboard is caused to rotate by a small clock. The separate parts are mounted on the wooden frame and register through pen levers by means of special ink on the cardboard disc. The pressure and humidity are recorded side by side on one half of the disc and the temperature and wind velocity diametrically opposite on the other half of the disc. The barometer consists of a single aneroid, to the centre of which is soldered a projecting piece, which operates directly on the short arm of the pen lever. The thermometer consists of a long spiral copper tube filled with alcohol, and carrying at one end a small thin-walled box similar in shape to an aneroid box. The tube is fixed to the under side of the frame, but the box projects through to the upper side. A projecting piece soldered to the middle of the free side of the box operates directly on the short arm of the pen lever. The hygrometer consists of a bundle of hairs enclosed in a ventilation tube situated in the under side of the frame, and the movement is transmitted to the pen by levers fixed to a spindle passing through the frame. The anemometer is actuated by the pressure of the wind on one or several light spherical balls suspended by about 40 feet of thread attached to the end of a lever pivoted on the instrument frame. The pull is balanced by a spiral spring, so arranged that the deflection of the recording pen is proportional to the wind velocity.

[1] Symons, *Met. Mag.*, vol. xxxix. 1904, p. 109.

The Marvin and Hergesell instruments are in general suspended from the wire some distance below the kite, so that the indications of the anemometer shall not be influenced by disturbances due to the kite. The Dines instrument is suspended in the centre of the kite, the anemometer thread being so long that the ball is out of range of the disturbances due to the kite. The method of attachment within the kite possesses considerable advantages in protecting the instrument from injury.

Ballons-sondes Meteorographs.—Of the different types of ballons-sondes meteorographs the first put into actual use was constructed by Richard. It was a baro-thermograph, having a multiple-cell aneroid barometer and a Bourdon tube thermometer filled with alcohol. The record was traced on a smoked sheet fixed to a clockwork drum. It was employed by Hermite and Besançon and by Hazen in 1893, and later, with various modifications, by Rotch at St. Louis, and in Russia.

The first instrument employed by Teisserenc de Bort was a baro-thermograph consisting of an aneroid barometer and a small, slightly bent Bourdon tube alcohol thermometer. He found, however, that the aneroids showed considerable elastic after-effect,[1] and replaced them by a Bourdon tube barometer, which proved more consistent. The lag of the reservoir thermometer also led him to construct a metal thermometer whose thermal inertia was much smaller. This consisted of a strip of German silver 0·1 mm. thick, 250 mm. long, and 9 mm. broad, mounted in a nickel-steel frame, the expansion of the strip being multiplied two hundred times by a lever. In its final form his instrument consists of a Bourdon tube barometer, a bimetallic thermometer, and a hair hygrometer. The th rmometer is a compound strip of brass and steel soldered together. Th s strip has the form of a nearly closed ring, one end of which is fixed to the frame of the instrument, but insulated from it by a block of rubber, and the other is connected through levers to the recording pen. The block of rubber serves to prevent conduction of heat from the frame of the instrument, a source of error in previous instruments amounting to several degrees C. The scale of the instrument is :—

1 mm. of mercury = about 0·08 mm. deflection.
1° C. = ,, 0·4 mm. deflection.

During an ascent the thermometer tube and the hygrometer hairs are exposed, but the rest of the instrument is enclosed in a cork case. The whole is slung by springs, inside a basket open at top and bottom, but lined round the sides with nickel paper.

Hergesell designed a similar compound strip metal thermometer, but abandoned it owing to changes of zero produced by the straining of the soldered joint when the strip was distorted at low temperatures during the ascent.

His final design included a Bourdon tube barometer, a hair hygrometer, and two thermometers. One of these latter is a bimetallic thermometer of the type used by Teisserenc de Bort. The other consists of a long, thin German-silver tube supported from its upper end by three nickel-steel uprights screwed into the base plate. The lever which operates the recording pen is fixed to the lower end of the tube, and is moved by the expansion or contraction of the tube. The tube projects through the base plate of the instrument, so that during the ascent a continuous current of air passes through it. The pressure, humidity, two temperature traces,

[1] Vide *Compt. rend.*, July 11, 1898.

and the zero trace are marked side by side on the usual smoked aluminium sheet fixed to a revolving drum. The scale of the instrument is :—

1 mm. mercury = 0·1 mm. deflection.
1° C. = 0·7 mm. deflection.

The clock is of invar and is guaranteed not to stop even at −80° C. The instrument is provided with a protecting case and weighs 750 gm. There is no forced ventilation, the rate of rise and fall of the balloon being deemed sufficient protection against solar radiation. In an ascent the instrument is suspended by springs in a basket lined at the sides with nickel paper.

In order to reduce the weight of the instrument for use with small rubber balloons Assmann abandoned the heavy clockwork, and, after various modifications, devised the following instrument. Two cylinders free to rotate and with their axes parallel are mounted one above the other in the frame, and the record sheet forms an endless belt round them. One of the cylinders is turned on its axis by the expansion or contraction of the multicellular aneroid barometer, and the other cylinder and the record sheet move with it. The thermometer pen is carried across the sheet, parallel to the axes of the cylinders, by an endless thread passing round two pulleys, which are caused to turn by levers connected with a bimetallic thermometer consisting of copper and invar strips soldered together. The pressure is thus indicated by the movement of the record sheet, and the temperature by the movement of the pen across the sheet, the two motions being exactly at right angles to each other. The humidity is indicated in the same way as the temperature, a double-span hair hygrometer being used. A small clock draws a pen across the record sheet to indicate the duration of the ascent, and to show if the balloon burst instantaneously on reaching the maximum height. Stoppage of the clock does not materially affect the results. The thermometer strip and the hygrometer hairs are enclosed in a ventilation tube, and in some of the instruments are aspirated by means of an electrically driven 'Scirocco' fan fixed into the ends of the ventilation tube. The total weight of instrument and case is 620 gm.

The Dines meteorograph is of quite different design.[1] It is a barothermograph, no measurements of humidity being attempted. The barometer is in general a partially exhausted German-silver aneroid, and the thermometer is bimetallic, consisting of a strip of aluminium or German silver and a rod of invar. The partially exhausted aneroid is used because it gives a larger scale than the totally exhausted box.[2] In the Assmann instrument the record sheet moves bodily, while the barometer and thermometer elements are fixed; in the Dines instrument the same effect is obtained by making the barometer and the record sheet fixed, while the thermometer moves bodily. The aneroid is fixed on one side to the frame of the instrument, and on its other side carries the thermometer. When the aneroid expands or contracts the thermometer is moved laterally as a whole, and the two pens, being attached to the thermometer, are carried across the record sheet and mark two similar and parallel pressure traces.

The German-silver strip and the invar rod of the thermometer are approximately of equal length, straight and parallel to each other, and are separated slightly. They are fixed together at one end, and the

[1] Symons, *Met. Mag.*, July 1906, p. 101.
[2] The original and perhaps more important reason was to utilise, as far as possible, the more perfect elasticity of a gas instead of that of a metal. The boxes containing air have very little lag.

thermometer pen lever is pivoted to the two free ends. The expansion or contraction of the German-silver strip causes the thermometer pen to move at right angles to the pressure traces. The traces are marked by two sharp steel styles on a roughly silvered metal plate. The scale of the instrument is :—

1 mm. mercury = about 0·04 mm. deflection.
1° C. = ,, 0·02 mm. deflection.

The instrument with its case of polished aluminium, open at both ends, weighs only 55 gms.

III. (*b*)—*Testing of Instruments.*

Kite Instruments.—The barometer of the Richard, Marvin, and Hergesell-Bosch kite instruments is tested under the receiver of an air-pump, by exhausting in steps. The pressure at each step is indicated by a mercury manometer. The barometer error due to temperature change is inappreciable at the heights reached by kites for the majority of the instruments. In those for which this is not the case, either a correction is applied as subsequently described for ballons-sondes instruments, or the aneroid or tube is replaced. In the case of the Dines instrument, however, the effect of temperature changes on the partially exhausted aneroids is considerable, owing to the contraction of the enclosed air and the comparatively thin German-silver walls of the box. The temperature correction is determined by placing the instrument in an alcohol bath, which may be cooled by carbonic-acid snow, and exhausting in steps at various temperatures.

The method is rendered clear by the following table :—

Temperature	Height Indicated	Corrected Height	Correction
°C.	Metres	Metres	Metres
51	0	0	0
	610	610	0
	1220	1235	15
	1830	1845	15
	2440	2470	30
	3050	3080	30
0	− 490	0	490
	0	490	490
	610	1110	500
	1220	1720	500
	1830	2350	520
	2440	2960	520
	3050	3580	530
−10	− 820	0	820
	0	820	820
	610	1450	840
	1220	2060	840
	1830	2680	850
	2440	3290	850
	3050	3900	850
−20	−1170	0	1170
	0	1170	1170
	610	1780	1170
	1220	2410	1190
	1830	3020	1190
	2440	3640	1200
	3050	4250	1200

The correction is thus :—

$$\Delta h = 0{\cdot}01h + 32{\cdot}4(T_0 - T_1).$$

Δh = correction in metres.
h = height indicated.
T_0 = temperature at ground level in ° C.
T_1 = temperature at height $h + 0{\cdot}01h$.

The thermometers are tested by immersing them in a bath of alcohol cooled by carbonic-acid snow, the temperature being indicated by a standard pentane thermometer.

The hair hygrometers are compared on the Continent with the aspiration psychrometer, and in England with the ordinary wet and dry bulb, the humidity being varied by means of sulphuric acid of different degrees of concentration or by other like means. 100 per cent. is obtained by wetting the walls of the enclosure.

The Robinson and Assmann anemometers are compared with the indications of a standard instrument, the two being exposed together, or are placed in an artificial air-current of known velocity produced by a Scirocco fan. The Dines' anemometer is calibrated by hanging various weights on the thread of the instrument, each weight corresponding to the pressure of a definite wind-velocity on the spherical balls, predetermined by Mr. Dines. For example :—

Test of Dines' Anemometer.

Weight		Deflection	Corresponding Wind Velocity m.p.s.
gm.	grs.		
8	123	1·4	4·5
10	154	1·7	7·0
20	308	2·2	11·2
30	463	2·7	13·9
50	772	3·7	18·2
70	1080	4·7	21·5
80	1235	5·2	23·1
90	1389	5·7	24·7

Ballons-sondes Instruments.—The second meeting of the International Committee at Strassburg (April 1898) recommended that the ballons-sondes instruments should be tested as nearly as possible under the same conditions as those encountered during the ascent, and, if possible, to temperatures and pressures lower than those actually experienced.

In the method of testing adopted by Teisserenc de Bort, the whole instrument was placed under the receiver of an air-pump and the pressure was lowered in stages down to about 50 mm. of mercury. The indications of the instrument at various pressures and atmospheric temperatures were thus obtained.

To test the thermometer the Bourdon tube, or compound strip, was immersed in a bath of alcohol, the rest of the instrument being above the level of the liquid. The alcohol was then cooled by means of carbonic-acid snow to various temperatures down to −75° C. Teisserenc de Bort found that the Bourdon tube alcohol thermometers were satisfactory.

The aneroid barometers were less accurate, the elasticity of the boxes being imperfect and giving rise to a considerable lag and to changes of zero after being subjected to low pressures.[1] The effect of temperature

[1] *Compt. rend.*, July 11, 1898.

on the indications of the aneroids was not examined, and it was assumed that errors due to this cause would be negligible in comparison with the general accuracy of the observations. With this method of testing, Teisserenc de Bort found that his maximum barometric heights in ascents from 1899–1903 agreed on the average with trigonometrical observations to nearly ± 1 per cent. up to heights of 10 kms., and at 4 kms. the difference was negligible.[1] The error was not wholly due to the temperature coefficient of the barometer, but partly also to the lag of the instrument. Later observations indicated an average error of $\pm$ 2 per cent. at the maximum height and a very considerable lag at the lower altitudes.[2]

After the work of Hergesell and Kleinschmidt on the temperature coefficients of the barometers[3] Teisserenc de Bort began to test this effect, but instead of applying corrections for the temperature he replaced all tubes having too large a coefficient by new ones whose temperature coefficient was negligible.

During the past two years, in accordance with the suggestions of Hergesell, certain of the barometers have been tested at various temperatures down to $-50°$ C., and it has been found that the majority of the barometric heights above 13 to 14 km. are too low by at least 0·5 km. At 20 km. the correction is often 2 km. and even more. Many attempts have been made to eliminate this effect of temperature, but they have not been altogether successful. When the temperature correction is applied it is specially noted in publication. It may be pointed out that the application of the temperature correction to the Teisserenc de Bort barometer is not easy, as the Bourdon tube is enclosed in a cork case and its temperature in an ascent is not accurately known. The thermometers are compared every two or three months with a standard thermometer in an alcohol or petrol bath cooled to $-70°$ C. with carbonic-acid snow, the alcohol being continually agitated.

The methods of testing the instruments employed in the ascents from St. Louis, U.S.A., in 1904–07 were similar to those of Teisserenc de Bort. The barometer was tested under the receiver of an air-pump, and the thermometer by means of a mixture of alcohol and carbonic-acid snow down to a temperature of $-83°$ C. No correction was applied for the temperature coefficient of the barometer.

A similar method of testing is adopted at the Observatoire Constantin, Russia.

In Germany the usual method of testing is different, and correction is made for the temperature coefficient of the barometer.

At the Lindenberg Observatory the barometer is tested by placing it under the receiver of an air-pump and exhausting to various pressures. The air-pump receiver, which is of metal, has triple cavity walls through which carbonic-acid gas is allowed to circulate. The temperature is thus reduced to various values and the temperature correction of the barometer determined for different pressures. The air inside the receiver is kept in vigorous circulation by an electrically driven fan, and the temperature is indicated by a standard thermometer viewed through a double-glass window designed to be free from condensation of moisture on its faces. The thermometer of the instrument is calibrated at the same time. The exhaustion is carried down to about 50 mm. and the temperature to

[1] *Brit. Assoc. Reports*, 1903, p. 551.
[2] *Compt. rend.*, **141**, pp. 153–155, July 10, 1905.
[3] *Beiträge z. Physik der Freien Atmosphäre*, **1**, 1905, pp. 108, 208.

$-60°$ C. The hygrometer is compared with an aspiration psychrometer in an enclosed space.

This method of testing necessitates somewhat elaborate apparatus, and in the German ascents, other than those made at the Lindenberg Observatory, the method employed is similar to that of Teisserenc de Bort.[1] The temperature coefficient of the barometer is determined by immersing the instrument (the clock having been removed) in the alcohol bath, and reducing the temperature. In some cases, instead of alcohol, acetone or petrol is employed. Any Bourdon tube or aneroid which has too large a temperature coefficient is replaced by a new one. The temperature correction of the barometer is applied in the form proposed by Hergesell and Kleinschmidt,[2] viz. :—

$$\Delta p = -\Delta T (A - \alpha p),$$

where Δp is the pressure correction to be found,
ΔT the fall of temperature,
A, a constant varying with different instruments,
α, a constant for a given type of instrument,
p, the pressure uncorrected.

The constant α, according to Hergesell and Kleinschmidt, is 0·00046 for the Bosch-Bourdon tube and 0·00064 for that of Richard.

For a typical Bosch-Hergesell instrument the correction was given by the equation :—

$$\delta p = -\Delta T (0{\cdot}48 - 0{\cdot}00046 p).$$

In Germany, Kleinschmidt also tests the hygrometers at different temperatures. He found[3] that the length of the hairs was independent of the pressure and almost independent of the velocity of the ventilating air-current. The hygrometer was affected little by variations of temperature between $+20°$ C. and $+5°$ C., but became very sluggish below $-10°$ C. It recorded slow variations fairly well at $-30°$ C., but was not even qualitatively suitable at $-40°$ C.

Test of Dines' Ballon-sonde Barograph.

Temperature	Deflection	Pressure	Deflection
°C.	mm.	mm.	mm
15	+0·30	760	0·60
		600	3·35
		300	10 78
		50	15·85
0	0·00	760	0·0
		600	2·76
		300	10·00
		50	15·28
−30	−0·60	760	−1·20
		600	+1·58
		300	8·72
		50	14 75
−60	−1·20	760	−2·30
		600	+0·38
		300	7·58
		50	14·24

[1] At Munich, Schmauss places the instrument in an air chamber surrounded by an alcohol bath. The air is thoroughly mixed by means of two fans.

[2] *Beiträge z. Physik der Freien Atmosphäre*, **1**, 1905, pp. 108–119, 208–210.

[3] *Ibid.* **2**, 1906–07, p. 99.

He standardises the instruments (1) at normal pressure in moist and dry atmosphere ; (2) at reduced pressure and temperature in moist and dry atmosphere.

In testing the Dines instrument the whole instrument is placed in an alcohol bath under the glass receiver of an air-pump. In this way the temperature correction of the barometer is found, at the same time as the thermometer is tested, by cooling the bath to various temperatures with carbonic-acid snow and exhausting the receiver in steps down to about 50 mm. at each temperature.

Allowance is made for the pressure due to the depth of submersion of the aneroid in the alcohol. The alcohol is kept in circulation by the vigorous boiling off of the carbonic acid. (This is sufficient at times to make the liquid boil over the sides of the reservoir.)

The temperature correction is more complicated than that of other instruments owing to the aneroid being only partially exhausted. It cannot be represented by a simple mathematical formula. A separate calibration curve is therefore drawn for each temperature, and the corrected pressures are read off from the curves.

The temperature scales of all the different types of instruments are found to be linear, and the temperatures are calculated by means of a coefficient.

The hygrometer scale is not quite uniform, and a correction is applied to the humidity indicated.

Accuracy of Results.—The possible errors which may arise in observations by means of kites have been practically eliminated by the construction of instruments almost completely unaffected by the shocks which occur during an ordinary ascent.

No appreciable error can arise from solar radiation, because the wind which is necessary to raise the kite provides sufficient ventilation. The lag of the Marvin instrument is 1° F. when the temperature changes at the rate of 1°·5 F. per minute, corresponding to the ordinary rise or fall of the kite at the rate of 500 feet per minute.[1] The lag of other instruments is less.

The effects of solar radiation in manned and captive balloon observations on the Continent have been minimised by the use of aspirated instruments, while in England such ascents are made either near sunset or before sunrise, except when the sky is completely overcast.

The chief errors in the observations arise in the ballons-sondes results.

At the extreme heights reached by free balloons solar radiation is very intense, and may raise the temperature of an unventilated thermometer as much as 50° C. above that of the air.[2]

This effect has been largely eliminated by the use of rubber balloons and instruments enclosed in highly polished ventilation tubes, and in many of the Assmann instruments by the additional precaution of aspiration by means of an electrically driven fan giving a current of 4 to 5 m.p.s. The lag of the instrument has been diminished by the use of Bourdon tube barometers, the bimetallic thermometers of Teisserenc de Bort and Dines, the tube thermometer of Hergesell, and ventilation tubes.

The ventilation produced by the ascent of the balloon is now generally

[1] *Frank. Instit. Journ.*, **148**, pp. 241–259, October 1899.

[2] Assmann, *Preuss. Akad. Wiss. Berlin, Sitz. Ber.*, **24**, pp. 495–504, and *International Ascents Pavlovsk*, November 8, 1906.

accepted by observers as sufficient. Experiments have been made in which the barometer, by completing an electric circuit at a given low pressure, set into motion a ventilating fan, producing a current of 3–4 m.p.s. No discontinuity in the temperature trace was produced, showing that the effect of radiation in the isothermal zone was negligible under the conditions of the ascent.[1] It is also found that instruments of different types sent up together give results which are in good agreement. Thus in comparisons of the bimetallic thermometer of Teisserenc de Bort with the tube thermometer of Hergesell, the maximum difference between the temperatures indicated was 7°·3 C., and the average difference was about 2° C.

Comparisons of the Hergesell-Bosch with the Assmann instrument gave a maximum difference of temperature of 4°·1 C. and a mean difference of 1°·7 C.

The maximum difference between the temperatures indicated by two Dines' instruments sent up from Manchester was only 4° C. and the average only 1° C.

Tables typical of the comparisons of various instruments are given.

Comparison of Hergesell and Teisserenc de Bort Thermographs.[2]

Height	Temperature		Height	Temperature	
	Hergesell	L. T. de Bort		Hergesell	L. T. de Bort
Km.			Km.		
1	+ 1·2	+ 1·2	7	−33·0	−33·4
2	− 2·5	− 2·7	8	−39·8	−40·2
3	− 4·9	− 4·9	9	−47·5	−48·0
4	−11·5	−11·8	10	−54·5	−55·5
5	−18·5	−19·0	11	−59·4	−61·2
6	−26·3	−27·1	12	−60·9	−62·9

Comparison of Hergesell and Assmann Thermographs.[3]

Height	Temperature		Height	Temperature	
	Hergesell	Assmann		Hergesell	Assmann
Km.			Km.		
1	9·9	7·0	10	−53·3	−52·8
2	3·8	0·0	11	−51·3	−52·1
3	− 2·4	− 6·6	12	−50·8	−52·0
4	− 9·2	−12·8	13	−50·6	−52·5
5	−16·8	−19·9	14	−51·4	−51·9
6	−25·7	−29·8	15	−54·7	−51·7
7	−35·0	−38·6	16	−53·3	−51·7
8	−44·5	−48·2	17	−52·4	−51·8
9	−54·5	−53·9			

[1] *Ergeb. der Arbeit. am Aër. Obs. Lindenberg*, 1907, p. xiii.
[2] *Ibid.*, 1906, p. 103.
[3] *Ibid.*, 1905, p. 99.

Comparison of two Dines' Thermographs.[1]

Height	Temperature		Height	Temperature	
	No. 90	No. 94		No. 90	No. 94
Km.			Km.		
1	− 1	− 3	12	−56	−54
2	− 7	− 9	13	−55	−54
3	−13	−15	14	−55	−54
4	−19	−22	15	−55	−54
5	−24	−26	16	−55	−56
6	−30	−32	17	−55	−56
7	−34	−37	18	−56	−57
8	−40	−43	19	−57	−57
9	−46	−50	20	−58	−59
10	−52	−54	21	−59	−60
11	−56	−54	22	−60	−60

A. de Quervain in 1906 estimated from the results of his own and Hergesell's experiments the probable maximum and mean errors of the various thermometers due to lag.[2] His results may be tabulated as follows :—

Instrument	Maximum error for fall of 4° C. per min. with ordinary ventilation	Probable mean error under ordinary working conditions
Hergesell-Bosch Tube . . .	0·95° C.	0 0°C.
Teisserenc De Bort New Bimetallic .	1·0	0·5
„ „ Old „ .	2·5	0·7
Bourdon Tube	2·5	—
Assmann Copper-Invar . . .	3·8	1·4
Bosch New Bimetallic . . .	2·4	—
Kusnetzow (ring-shape bimetallic) .	2·2	—

In continuation of the work of Hergesell and Maurer he examined (1) the small Bourdon tube thermograph of Teisserenc de Bort : German-silver tube slightly curved and filled with alcohol ; (2) the bimetallic lamellar thermograph of Teisserenc de Bort : strips of brass and steel soldered together and bent into a circle ; (3) the tube thermograph of Hergesell : German-silver tubes on supports of nickel-steel ; (4) the bimetallic thermograph of Assmann : copper and nickel-steel ; (5) the Kusnetzow bimetallic thermograph : brass and nickel-steel bent into an S curve. The first three had often been used simultaneously.

He concluded that (1) and (2) were in good agreement, (3) generally marked 0°·6 C. less than (2), and indicated lower amplitudes at sudden changes, though on the whole more sensitive than (2).

He concluded that the mean error for the pressure records was ±2 mm. and for the temperatures ±2° C., so that the temperature gradients for 1000 m. intervals are reliable to a few tenths of a degree C.

A slight error is introduced into the bimetallic thermometer calibrations through change of zero by straining of the soldered joint. The Hergesell-

[1] *Weekly Weather Report*, February 28–March 6, 1909, p. 76.

[2] *Beitr. z. Physik der Fr. Atmos.* i. p. 163, 1906 ; *Zeitschr. f. Instrumentenk.*, 27, pp. 127, 128 ; April, 1907.

Bosch tube thermometer is free from this defect, but has other faults, pointed out by Schmidt and Gold, which prevent the possibility of its giving quite accurate results.[1] The possible calibration errors of the Dines instrument are somewhat larger, as the scale is microscopic, the calibration curves of the barograph are not linear, and the temperature correction is not a simple function.

The average error found from independent calibrations is 0°·1 C. for Continental instruments and 0°·8 C. for the Dines instrument at the lowest temperatures. For higher temperatures the possible error is of the same order of magnitude. The principal error in the temperature traces probably arises purely from faults of construction in the instrument, such as insufficient rigidity and sticking of the pens. The best way of eliminating these defects is probably to increase the rigidity by simplifying the construction and diminishing as far as possible the number of levers, joints, and bearings, so that the working parts operate as directly as possible on the recording pens.

The heights indicated by the barometers have many times been compared with the heights calculated from trigonometrical observations, and the maximum heights have been found correct to ± 2 per cent. up to 10 km.[2] The intermediate heights show greater errors with some instruments, owing to lag. An example given by Teisserenc de Bort showed large differences[3], *e.g.* :—

Height	Ascent. Difference kms. between Barometric and Trigonometric Heights	Descent. Difference
Km.	Km.	Km.
4	1	−0·6
8	0·4	−0·4
Max. height	0.1	0·1

This instrument was specially chosen to show the effect.

The average error in pressure of the Continental instruments amounts to 5 mm. of mercury and that of the Dines instrument to 8 mm. The errors to which these give rise in the final results are as follows :—

Heights, km.	5	10	15	20
Difference corresponding to :	Km.	Km.	Km.	Km.
5 mms.	0·1	0·2	0·4	0·6
8 mms.	0·2	0·3	0·5	1·0

The errors introduced in working up the traces are very small in Continental instruments owing to their large scale, and for the Dines instrument are of the same order as those occurring in the calibration. The principal error in the final results arises from the uncertainty of the temperature correction of the barometer. Teisserenc de Bort estimates the correction due to this cause to be 0·5 km. at 14 km., and 2 km. or even more at 20 km. Hergesell, however, claims to have shown that

[1] *Quart. Journ. Roy. Met. Soc.*, 1909, *Met. Zeit.*, 1909.

[2] L. T. de Bort, and *Étude de l'Atmosphère*, Observatoire Constantin, Fascicule ii. p. 75.

[3] *Compt. rend.*, July 10, 1905, p. 153.

the correction is considerably larger, amounting for some instruments to as much as 5 or 6 km. at 25 km.[1]

The indications of the thermometers are open to no such objections, and from the inter-comparison of different types of instruments it may be stated that the temperature is known to within $\pm 1°$ C.

The indications of the hair hygrometer are considerably less accurate, as was shown by Kleinschmidt.[2] The instrument is quite unsatisfactory for work at high altitudes, and is unreliable at heights where the temperature is below $-5°$ C., *i.e.*, at heights greater than about 5 kms.

IV.—(*a*) *Mean Temperatures and Gradients of Temperature.*

The most important meteorological element of which observations can be made in the free atmosphere is temperature. Observations of pressure furnish practically the only means of estimating heights, and they cannot therefore be used to determine directly the distribution of pressure. The latter can only be determined indirectly by calculation from the observations of temperature and the pressure at the surface. Thus, while dynamical meteorology must necessarily be based on a knowledge of the pressure and density distributions, it rests ultimately on the distribution of temperature, and in a lesser degree on that of humidity, in the free atmosphere. The calculations are obviously laborious even when sufficient observations are obtained; the difficulty and expense of obtaining the observations make the task appear almost hopeless. Thus no really serious attempt has been made to calculate from observational data the actual synchronous distribution of pressure in the upper atmosphere at 5–10 km. altitude at times when the surface distribution is meteorologically most interesting. Our knowledge is confined practically to mean values.

In order to avoid as far as possible negative quantities and to facilitate calculation and comparison, temperatures have been usually expressed in degrees C. above the absolute zero—273° C. on the ordinary scale. Atmospheric temperatures in temperate latitudes lie almost invariably between 200° and 300° on this scale, and the initial 2 may be generally omitted without risk of confusion. The letter A is used in connection with this scale; thus (2)73° A is 0° C. Further, the vertical gradient of temperature is expressed in degrees C. per kilometre and is reckoned positive when temperature diminishes with increasing height.

The most complete contribution hitherto made to the discussion of upper air observations is that of Von Bezold, Assmann, Berson, and Süring[3] who dealt with the observations obtained from manned balloons. The following table gives the values they found for the gradient of temperature for each kilometre up to 9 km.:—

Height	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9 km.
Gradient	5·0	5·0	5·4	5·3	6·4	6·9	6·6	7·2	9·0
Number of Cases	59	57	42	38	23	13	5	5	2
Probable Error in Gradient	—	—	—	—	0·1	0·3	0·5	0·6	—

In the surface layer the gradient is affected by inversions, *i.e.*, exceptional cases where the temperature increases with the height. Such cases occur most frequently in winter, and as the number of winter ascents in the

[1] *Ergeb. der Arb. am Aër. Obs. Lindenberg*, 1906, p. iii.

[2] *Beitr. z. Physik der Fr. Atmos.*, Bd. ii., Heft i. p. 99, 1906–1907.

[3] *Wissenschaftliche Luftfahrten*, Braunschweig 1899, 3 vols.

series was considerably less than that for other seasons, the actual mean annual gradient in the lower layer is less than that deduced from these results. The values of the gradient for the first two layers when cases of inversion are excluded are 6·4, 5·4, respectively.

The following values have been deduced from the later manned balloon observations, 1901–07 :—

Height	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10 km.
Gradient	4·3	5·1	5·1	5·8	6·2	6·9	7·5	6·2	3·7	8·3
Number of Cases . .	50	50	44	40	34	22	10	3	1	1
Probable Error in Gradient	—	—	0·2	0·2	0·2	0·2	0·4	0·6	—	—

The feature to which Berson drew particular attention was the comparative constancy of the gradient up to a height of 4 km. and the very considerable increase in its value in the next layer. The more recent observations do not show the peculiarity so markedly and indicate a lower level for the discontinuity. Berson attributed the change to the fact that the upper limit of the lower clouds is nearly at 4 km. altitude, and near this height inversions are more frequent than in the layer above and below it. From actual observations in the clouds themselves he deduced that the gradient there agreed remarkably well with the theoretical gradient for saturated air rising adiabatically, which we may call g_s. Just beneath the upper limit of the cloud an increase in the gradient was usually observed, and just above the upper limit the gradient vanished and the air immediately above the cloud was generally found to be warmer than that beneath its upper surface. It may be noted that the value of g_s between 5 and 7 km. is approximately 7° C. per km., agreeing closely with the value found for this region. The mean values for the gradient for each 500 m. up to 3,000 m., deduced from the monthly mean temperatures found from the kite and kite-balloon ascents made at Berlin and Lindenberg, 1903–07,[1] are as follows :—

Height . . .	0–0·5	0·5–1·0	1·0–1·5	1·5–2·0	2·0–2·5	2·5–3·0
Gradient . . .	5·5	4·6	4·4	4·8	4·0	5·0

These values differ considerably from the corresponding values for the manned balloon ascents. This may be due to the fact that the kite ascents are distributed throughout the year, and are made under a greater variety of weather conditions. The large surface value is to be attributed partly to the fact that most of the ascents are made between 8 and 10 A.M., and the temperature gradient to 500 m. at that time is above the mean temperature gradient for the day.

Gold[2] showed that the gradient up to 2 km. depended very considerably on the wind direction as well as on the time of the year. He found that inversions were most frequent in winter and with easterly winds; that they occur very rarely indeed with N.W. winds, and then in summer, a season when they are not found with winds from other directions.

Field[3] made kite ascents in India and over the Arabian Sea during the S.W. monsoon, and found a very rapid decrease of temperature up to 300–400 m. At greater heights up to 3,000 m. the gradient was very close to that for saturated air rising adiabatically, *i.e.*, about 5° C. per km.

Hann[4] deduced from mountain observations that the mean temperature gradient up to 3 km. is 5°·7 to 5°·8 per km. The earlier balloon

[1] *Ergebnisse Aeronautischen Observatoriums*, Berlin and Lindenberg.
[2] *Barometric Gradient and Wind Force*, M.O., No. 190.
[3] *Indian Met. Memoirs*, vol. xx. part 7.
[4] *Lehrbuch der Meteorologie*, p. 104.

ascents give for the mean value 5·1, the later 4·8, while the kite ascents give 4·7. It is therefore to be expected that the mean temperature of the air in contact with a mountain 3,000 m. high will be 2° to 3° C. below that at the same height in the free atmosphere. The elevated parts of the earth's surface exercise a cooling influence on the upper air, *i.e.*, the mountains are not cool because the upper air is cooled by adiabatic convection, but they are cool because of radiation to space. It follows from this that convection does actually raise the temperature of the atmosphere up to 3 km. altitude above what it otherwise would be, a fact pointed out from theoretical considerations by Gold.[1]

The results of direct comparison of simultaneous observations are in agreement. Berson[2] found from a comparison of the temperature observed in balloons with that observed on the Brocken (1,140 m.) that the mountain was 0°·9 C. colder than the free atmosphere.

Shaw and Dines[3] found from twenty-eight kite ascents made in July, August, 1902, that the temperature on Ben Nevis (1,343 m.) was in all cases lower than that in the free atmosphere at the same height over the sea to the west of the mountain, the mean difference being 2°·6 C. Additional evidence in support of their result was furnished by the fact that the height at which the kite reached the clouds was invariably greater than the height at which the clouds were observed over the neighbouring hills. They suggested that the difference might be due to the westerly stream of air rising to cross the mountains and producing an approximately adiabatic gradient of temperature.

Schmauss[4] has recently considered the simultaneous values observed on Zugspitze (2,965 m.) and recorded at the same height in balloon ascents from Munich, 90 km. distant. He found a mean difference of 1°·6 C. between the synchronous temperatures, and 1°·1 C. between the temperature recorded in the free atmosphere and the mean temperature of the day at Zugspitze. In both cases the free atmosphere had the higher temperature. Schmauss deduced also from a comparison of the temperatures on Zugspitze and Sonnblick that the latter was 0°·6 C. colder than the former at the same height, and consequently a mountain in the middle of a mountainous district is colder than one on the edge of such a district. This may be taken as further evidence that the atmosphere is cooled by the mountain.

In dealing with the registering-balloon results, the mean temperatures at each kilometre for each month of the year have been formed for ten stations: Berlin, England (Pyrton Hill, Ditcham Park, and Manchester), Koutchino by Moscow, Munich, Paris, Pavlovsk (near St. Petersburg), Strassburg, Uccle, Vienna, Zurich. From these means the mean yearly temperature at each height has been calculated for individual stations, and the mean monthly temperature at each height for the stations taken collectively.

The following table gives the mean gradient of temperature determined from the general mean values:—

Height . .	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8
Gradient . .	3·6	4·3	5·2	5·8	6·3	6·8	7·2	7·4
Height . .	8–9	9–10	10–11	11–12	12–13	13–14	14–15	
Gradient . .	6·8	5·0	3·3	0·7	−0·8	0·0	−0·1	

[1] *Proc. Roy. Soc.*, vol. lxxxii., 1909, pp. 47, 67.
[2] *Wissenschaftliche Luftfahrten.*
[3] *Phil. Trans. A.*, vol. ccii.
[4] *Registrierballonfahrten*, München, 1908.

The values agree on the whole with those obtained from kites and manned balloons, but they do not show the constancy of the gradient in the region 1–4 km.

The maximum value occurs in the layer 7–8 km. and indicates that in that region the effect of radiation is to leave practically unchanged the natural gradient in air in adiabatic vertical motion. This result is interesting in connection with Gold's [1] deduction that in the upper layers the absorption, being in excess of the radiation, tended to diminish the gradient by raising the temperature, while in the lower layers radiation, being in excess of absorption, tended to diminish the gradient by cooling. There must therefore be an intermediate height at which radiation and absorption exactly balance, and the results indicate that this is between 7 and 8 km. in temperate latitudes.

The values of the temperature at different heights deduced from the two series of manned-balloon ascents and by C. Abbe [2] from Teisserenc de Bort's registering-balloon ascents are given in the table :—

Height	0	1	2	3	4	5	6	7	8	9	10 km
First Series .	83·4	78·4	73·4	68·0	62·7	56·3	49·4	42·8	35·6	26·6	—
Second Series	81·6	77·3	72·2	67·1	61·3	55·1	48·2	40·7	34·5	30·8	22·5
Abbe . .	82	78	73	69	64	57	52	44	35	31	22

The results agree sufficiently to prove that they represent with fair accuracy the temperature of the air.

The following table gives the results for the ten stations, already enumerated, deduced from the registering-balloon ascents for 1904–08, or shorter periods where results for the full five years were not available. Stations from which the observations were obtained to the end of 1908 are marked with an asterisk.[3] Observations for England [4] from November 1907 up to May 1909 are included :—

Station	Munich*	Strassburg*	Paris	Uccle*	Vienna*	Pavlovsk	Koutchino	Zurich	England	Berlin	Mean
Approximate Height	516 m.	140 m.	100, 170 m.	100 m.	190 m.	30 m.	140 m.	480 m.	40, 170, 150	120 m.	
Surface	79·2	81·0	81·3	80·2	80·4	75·3	78·0	82·7	83·4	79·4	80·0
1	78·6	77·8	78·4	77·2	76·8	71·9	75·3	79·0	78·3	77·1	77·0
2	74·1	73·9	73·7	73·2	72·7	66·9	71·8	75·3	74·4	72·2	72·8
3	68·6	68·5	69·0	67·8	67·5	61·5	67·4	69·2	69·0	67·6	67·6
4	62·4	62·6	63·6	61·8	61·5	56·3	61·3	63·2	62·8	62·0	61·8
5	56·3	56·2	57·4	55·1	55·2	50·5	54·9	56·5	56·6	55·8	55·5
6	49·5	49·6	50·8	48·5	47·9	43·9	48·3	49·2	50·2	49·0	48·7
7	42·7	42·4	43·7	41·3	40·4	36·5	40·6	41·6	43·3	42·1	41·5
8	35·4	35·0	36·2	33·9	32·4	29·4	32·6	33·8	37·2	34·7	34·1
9	29·0	28·1	29·2	26·8	25·7	23·3	25·1	26·9	30·8	28·0	27·3
10	23·9	22·8	23·8	20·9	21·4	20·9	19·0	22·4	25·4	22·7	22·3
11	19·8	18·2	19·9	17·5	18·0	21·0	17·3	16·9	21·2	19·7	19·0
12	17·4	17·1	20·2	16·3	19·1	20·5	18·1	16·0	21·2	17·5	18·3
13	17·5	17·4	19·4	14·9	21·1	23·4	20·7	17·6	20·1	18·5	19·1
14	17·8	17·7	20·4	16·3	20·5	22·2	20·5	18·0	18·5	18·9	19·1
15	19·3	17·8	19·8	16·2	20·8	22·5	20·4	18·5	19·3	17·1	19·2

The temperatures at all the stations except Pavlovsk agree very closely. Paris and England have values slightly but uniformly higher

[1] *Proc. Roy. Soc.*, vol. lxxxii. pp. 67, 68.

[2] *Monthly Weather Review*, September 1899.

[3] The observations for Berlin and Zurich up to December 1907 are used. Those for Paris, Pavlovsk, and Koutchino up to September 1907.

[4] Pyrton Hill 150 m. Ditcham 170 m. Manchester 40 m. Glossop 340 m.

than the other stations. At Pavlovsk the temperature is continually lower than at the other places up to 10 km., after which it is higher than for the others. If the values for Pavlovsk are taken to be representative of the conditions for lat. 60° and those for Strassburg for lat. 50°, the mean difference of pressure between the two parallels at a height of 10 km. will be nearly 7 mm. if any difference in humidity is neglected. If allowance is made for the diminished density of the air at this height, it follows that such a difference of pressure would correspond to a steady W. wind of about 24 m.p.s. (metres per second).[1] Above 10 km. the temperature over Pavlovsk is higher than in lower latitudes, so that the difference of pressure would diminish with further increase in height. It would indeed diminish more rapidly than the density, so that the wind also would diminish in intensity above a height of 10 km. and the mean wind velocity would have a maximum value at about this height. It may be noted that the effect of the diminished proportion of water vapour present in higher latitudes would be to accentuate the difference of pressure in the upper air. The increase must however be small, and could not exceed 2 mm. even if the air over Pavlovsk were perfectly dry; the actual value is probably only a fraction of a millimetre.

The higher values found for Paris and in England indicate that there is a slight horizontal gradient of temperature from W. to E., and this will produce in the upper air a corresponding gradient of pressure also from W. to E. or from ocean to continent.

IV. (*b*) *Temperatures under Cyclonic and Anticyclonic Conditions.*

One of the most important questions which arise refers to the possible difference in the vertical gradient of temperature over cyclones and anticyclones. Hann [2] deduced from mountain observations that the gradient was less for anticyclones than for cyclones, and the difference was so considerable that the mean temperature of the atmosphere up to 3·5 km. was 5° C. higher over anticyclonic regions than it was over cyclonic. Grenander [3] used the observations made in the free atmosphere at Hald and Berlin and found similar results both for winter and summer. The following table gives the mean fall of temperature between the surface and 5 km. for the different quadrants in winter and the mean values for summer taken from Grenander's results:—

Quadrant	Winter					Summer
	N.	E.	S.	W.	Mean	Mean
Anticyclonic . .	24·3°	25·0°	19·4°	18·9°	21·0°	27·4° C.
Cyclonic . . .	26·5	26·9	28·7	30·6	27·7	29·9 C.

The mean temperatures at different heights, calculated from Grenander's results, are as follows:—

[1] The corresponding wind between lat. 40°–50° deduced by using St. Louis observations is 15 m.p.s.

[2] *Sitz. Wiener Akad.*, 1891.

[3] *Arkiv för Matematik*, &c., 1905.

Anticyclones.

—	Winter					Summer
	N.	E.	S.	W.	Mean	Mean
	° C.	° C.	° C.	° C.	° C.	° C
Surface about 60 m.	78·7	74·7	74·4	76·3	76·2	89·5
1 km.	74·4	70·0	71·1	75·2	73·2	82·4
2 „	71·3	64·9	68·4	72·7	70·2	77·3
3 „	66·3	60·4	65·3	68·8	66·2	73·3
4 „	61·1	55·7	60·5	63·6	61·3	68·4
5 „	54·4	49·7	55·0	57·4	55·2	62·1
Cyclones.						
Surface	79·9	77·5	79·8	78·8	77·0	88·7
1 km.	75·0	74·2	74·2	72·4	72·2	81·7
2 „	70·7	68·4	68·8	66·4	67·1	75·2
3 „	66·2	63·2	63·1	58·9	61·6	69·7
4 „	59·4	57·1	57·5	52·5	55·4	64·7
5 „	53·4	50·6	51·1	48·2	49·3	58·8

These results indicate that on the average the cyclones are colder than the anticyclones both in winter and in summer, the principal difference of temperature being found in the W. quadrant, while in the E. quadrant in winter cyclones are actually warmer than anticyclones. This is due partly to the fact that the cyclones have their lowest mean temperature in this quadrant and partly to the fact that on the whole anticyclones have their highest mean temperature in the same quadrant.

The N. quadrant of the cyclone is throughout very considerably warmer than the E. quadrant of the anticyclone, indicating that the direction of the gradient between these two regions would be reversed at moderate heights. For example, if the surface pressures were 750, 760 mm., the pressures over the two regions at 5 km. would be the same, 396 mm. nearly.

Berson deduced from the manned-balloon ascents the following values for the height of the 0° C. isotherm for different pressure distributions :—

	Front of Anticyclone	Anticyclone	Back of Anticyclone	Front of Cyclone	Back of Cyclone
Height	2850	2800	1580	2390	1120 m.

If 'front' and 'back' be taken to be the same as E. and W. the results agree with those of Grenander for cyclones, although the difference is considerably greater. But for anticyclones the difference between 'front' and 'back' is exactly the reverse of Grenander's results, and is much more accentuated. Grenander's results, however, refer to the winter, and the majority of the manned-balloon ascents were made in summer.

Hanzlik,[1] using chiefly mountain observations, has arrived at the interesting conclusion that in the layers up to 3 km. at least, anticyclones in Europe are of two kinds. Some are warmer and others colder than the normal.

A warm anticyclone is either the later development of an anticyclone,

[1] *Denkschrift*, Wien, 1908.

previously cold, which has become stationary with rising pressure in the centre, or it arrives in the European area as a warm anticyclone with slow indefinite translatory motion of the centre.

The cold anticyclone, on the other hand, remains cold if it moves quickly, but if it remains stationary for some time it gradually changes into a warm anticyclone.

Von Bezold deduced from the Berlin manned-balloon ascents that even up to 8 km. anticyclones were warmer than cyclones. The following table gives the values of the gradient for the different layers :—

—	Height in kilometres							
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8
Anticyclonic . .	3·8	4·0	5·3	5·4	6·4	7 2	7·1	7·7
Cyclonic . .	6·1	5 5	5·7	5 3	6·5	6·7	6·4	6·2
Intermediate . .	5·6	7·2	5·7	3·9	6·9	—	—	—

Thus the temperature falls by 4°·2 C. less in anticyclones than in cyclones in the first 5 km., after which the difference diminishes, but is still 2°·5 C. at 8 km.

The results from registering balloons have been taken for those cases in which the pressure, reduced to sea-level, exceeded 770 mm. and for those in which it was less than 750 mm. in order to obtain quite distinct distributions.

The following table gives the mean gradients for different layers up to 14 km. and the mean temperatures at the various heights :—

Height	Gradients				Temperatures	
	Pressure <750	No. of Cases	Pressure >770	No. of Cases	Pressure <750	Pressure >770
0	—	—	—	—	77·2	76·0
1	3 9	15	−0·45	51	73·3	76·5
2	5·5	15	2·6	51	67·8	73·9
3	5·6	15	4·45	51	62 2	69 4
4	6·4	15	5·65	51	55·8	63·8
5	6·45	15	6 4	51	49·3	57·3
6	6·45	15	6·8	51	42·9	50·6
7	7·25	15	7·2	51	35·6	43·5
8	6·35	15	7·8	51	29·3	35·7
9	4·3	15	7·4	50	25·0	28·3
10	2 7	15	6·5	48	22·3	21·7
11	1·4	14	5·6	46	20·9	16·1
12	−0 0	11	3·4	43	21·0	12·7
13	−0·0	9	1·0	35	21·0	11·7
14	−0·2	8	−0·7	29	21 2	12·4

If a correction is applied to the temperature owing to the irregular distribution of the ascents throughout the year and to the fact that four of the low-pressure cases are for Pavlovsk, which has a mean surface temperature about 5° C. below that of the other places, the surface temperatures for the low and high pressures become 81·8 and 78·4 respectively.

If we apply corrections to the gradient also, to allow for the unequal

distribution and for the undue influence of Pavlovsk, we obtain, as corrected values for the gradients in the two cases, the following values :—

—	Pressure <750	Pressure >770	T_1	T_2	T_3	T_m
0			81·8	78·4	80·1	80·0
	5·1	0·6				
1			76·7	77·8	77·0	77·1
	6·5	3·7				
2			70·2	74·1	72·7	72·8
	5·6	4·8				
3			64·6	69·3	67·5	67·6
	6·4	5·8				
4			58·2	63·5	61·7	61·8
	6·3	6·4				
5			51·9	57·1	55·4	55·5
	6·4	6·7				
6			45·5	50·4	48·6	48·7
	7·0	7·2				
7			38·5	43·2	41·4	41·5
	6·6	7·6				
8			31·9	35·6	34·0	34·1
	4·5	7·4				
9			27·4	28·2	27·2	27·3
	3·4	5·9				
10			24·0	22·3	22·2	22·3
	1·7	4 8				
11			22·3	17·5	19·0	19·0
	0·1	2·8				
12			22·2	14·7	18·7	18·3
	−1·2	1·0				
13			23·4	13·7	19·7	19·1
	0·3	−0·5				
14			23·1	14·2	19·6	19·1

The column T_1 gives the corrected mean temperature for pressure <750, T_2 that for pressure > 770, T_3 is the approximate mean temperature of the intermediate regions deduced from T_1, T_2, and the general mean T_m on the assumption that the influence of T_1, T_2 in forming the general mean is approximately proportional to the number of observations. The result is interesting as showing that anticyclonic regions are not only warmer than regions of low pressure, but also warmer, up to 10 km., than the intermediate regions, which appear to be colder at 9–10 km. than regions of high or low pressure.

If, in the centre of an anticyclone, b is the excess of pressure at any height above the normal pressure B for that height, and ρ is the density there, the value of the ratio $b/\rho d$ may be taken as a measure of the intensity of the anticyclone, where d is the mean distance of the isobar B from the centre of the anticyclone. Now as long as the temperature near the centre of an anticyclone remains higher than that in surrounding regions, the value of $b/\rho d$ increases with increasing height, and consequently the anticyclone increases in intensity. If b_1, d_1, are corresponding quantities for a cyclone, $b_1/\rho d_1$ increases with increasing height so long as the cyclone is colder than its surroundings. The values found above indicate that this is the case up to 8–10 km. Even at 14 km. the pressure over the anticyclonic region exceeds that over the cyclonic by more than 1 mm., which is as efficient in producing motion as a difference of 7 mm. at the

surface. The difficulty that arises is to discover a means by which air can be brought into the anticyclone and out of the cyclone in the upper air, and to make these results accord with the results of cirrus observations, which imply a definite outward motion over cyclonic regions and an inward motion over anticyclonic. At the same time it must be remembered that the cirrus observations do not imply that the anticyclone becomes a cyclone at the cirrus level or conversely; the direction of rotation is the same for the cirrus as at the surface according to Hildebrandsson's results, and this can be the case only if the direction of the gradient of pressure remains the same.

The results imply that the motion has a component across the isobars from the *lower* to the *higher* pressure. The difficulty of explaining this result was felt by earlier writers. Hann[1] expressed the opinion that the outward motion in cyclones was due to the centrifugal force of the motion exceeding the gradient. Although it is difficult to see how the necessary wind would be produced to bring about this state of affairs, it is at least a possible condition. If cyclones decreased in intensity with increasing height, and the air rising from the lower levels retained its angular momentum, it would indeed furnish a reasonable explanation.

The case of anticyclones is more difficult because the effect of centrifugal force is to assist the gradient of pressure in producing flow outwards. Gold[2] showed that in anticyclones there is a limit to the gradient and velocity for the motion to be steady and along the isobars. The approximate radii of isobars at the earth's surface differing from the pressure at the centre by 1, 2, 3, 4, 5 mm., are 260, 370, 450, 520, 580 km. for this limiting case. If the gradients are less than these, there will be a steady motion with correspondingly small velocities. If the gradients are greater than these, the motion cannot under any circumstances be steady, and there will always be an outward component in the wind, because the centrifugal force due to the increased velocity will more than counterbalance the increase in the force arising from the earth's rotation. The only possible case where there can be flow from low to high pressure for anticyclonic motion is when air enters a region where the gradients are less than the limiting gradients, with a velocity also less than that corresponding to the limiting gradient, but greater than that corresponding to steady motion for the actual gradient in the region. In that case the effect of the earth's rotation would be to make the air flow inward towards the centre. It seems improbable, however, that such a state could persist for any time, because the results of observation show that the wind usually adjusts itself to the gradient, provided it is at a sufficient height above the earth's surface to be practically free from the effects of surface friction and irregularities.

It seems more probable either (1) that anticyclones and cyclones arriving in the European area are in general dissipating systems, which are replaced continually by other systems arriving from what may be called productive regions, or (2) that there is interchange with regions in which the surface temperature or the temperature gradient is sufficiently different to produce mean temperatures greater in low-pressure areas and less in high-pressure areas than are found over Europe.

The results of observations of pilot balloons at Ditcham,[3] July 27–30, 1908, and at Munich,[4] during the same period, and September 30 to October 2,

[1] *Lehrbuch*, p. 406.

[2] *Barometric Gradient and Wind Force*, M.O. No. 190.

[3] *Quart. Journ. Roy. Met. Soc.*, 1908.

[4] *Registrierballonfahrten.*

1908, indicated that even to heights greater than 10 km. the wind had a component directed outwards from the region of high pressure, or was parallel to the general direction of the surface isobars and in the sense of the gradient wind at the surface. On January 3, 1908, on the other hand, the direction of the wind over Munich changed after 3–4 km., and the flow above this height up to 8 km. was directed inward towards the region of the surface high pressure. The English ascents indicate that the relative coldness of cyclones ceases at a lower altitude there than over the continent, and this tends to support the idea that the energy of the cyclonic motion is used up in extending the cyclone to greater heights and is gradually converted into the potential energy of the anticyclone. Finality can be reached only by an examination of individual cases in which the observations are extensive enough to furnish a good representation of the distribution of pressure and wind at great heights.

The results so far obtained show the need that exists for a series of ascents in the middle of the great Atlantic low-pressure system simultaneously with ascents in Europe and America. The general drift of registering balloons is from high to low pressures, although there are exceptions which are possibly due to the balloon entering at high altitudes a westerly current, which is caused by the general temperature and pressure distribution over the earth and may at times remain unaffected by shallow disturbances near the surface. The greater relative humidity over cyclones would tend to diminish the intensity in the upper air, but it is quite insufficient to bring about a reversal of the gradient between high and low pressure areas.

For the surface layers Gold [1] showed (1) that near the centre of cyclones the gradient of temperature up to 2 km. coincided very nearly with the adiabatic gradient for saturated air; (2) that in winter the gradient in the central region of anticyclones up to 3 km. was quite irregular, temperature increasing and decreasing in different layers in different ascents, but, on the whole, varying little from the surface value; (3) that in summer the gradient in the central regions of anticyclones was regular in the first kilometre and nearly equal to the adiabatic gradient for dry air, but that above this level the fall of temperature was frequently arrested, showing that the vertical circulation was purely a surface phenomenon and was not connected in any way with a general descending current of air. This shows that the air up to a height of 3 km. in anticyclones is practically an inert mass taking little part in the general circulation. The result may be compared with the deduction arrived at by Shaw and Lempfert [2] from a consideration of the air currents at the surface. They say, 'We have failed to identify the central areas of *well marked anticyclones* as regions of origin of surface air currents. . . . These latter are for the most part inert and comparatively isolated masses of air, taking little part in the circulation which goes on around them.' . . . 'The areas of descending air seem to be (*a*) the shoulders or protuberances of anticyclones, in particular the regions of comparatively high pressure between two consecutive cyclonic depressions, and therefore also between two anticyclones or (*b*) the extension of an anticyclone between a depression and its secondary.' If there is descending air in the upper atmosphere over an anticyclone (as indeed there must be if it maintains or increases its intensity) this air will not be considerably affected by radiation between 5 and 10 km., and the

[1] *Barometric Gradient and Wind Force*, M.O. No. 190.
[2] *Life History of Surface Air Currents*, M.O. 174, p. 24.

temperature gradient will remain nearly adiabatic, and will therefore allow a constant flow downwards. But when the air enters the region between the surface and 5 km. it will begin to be cooled by radiation, and the cooling will increase with approach to the surface, although in the surface layers themselves convection may reverse the process. Such cooling would be an effective bar to further direct downward convection and would allow only a gradual oblique convection by which the descending air would be transferred to the earth's surface, being cooled sufficiently by radiation in its progress to enable the convection to take place.

IV. (c) *The Advective and Convective Regions.*

Perhaps the most remarkable phenomenon revealed by the investigation of the upper air with balloons carrying self-recording instruments is the comparatively sudden cessation of the fall of temperature at a height varying with the time and the latitude. Above this height, which may be regarded as the height of an irregular but roughly horizontal surface dividing the atmosphere into two regions, the temperature at any time varies very little in a vertical direction, showing on the average a slight tendency to increase. This comparative absence of regular vertical variation of temperature in the upper region led to the name 'isothermal layer or region' to distinguish it from the lower atmosphere, in which the vertical variation of temperature is about 6° C. per 1,000 m. The first indication of a considerable falling off in the gradient appears to be contained in a paper by M. Pomortzeff [1] referred to by Berson in the discussion of the Berlin results. Pomortzeff tried to explain on theoretical grounds the diminution he found.

The actual cessation of the fall of temperature was first noticed by M. L. Teisserenc de Bort [2] in June 1899, and again in March 1902. It was also discussed shortly afterwards by Assmann.[3]

Teisserenc de Bort found the average height at which the change occurred to be about 11 km. He discovered also that the height was greater near centres of high pressure than near centres of low pressure, the average heights for the two cases being 12·5 and 10 km. respectively. Later observations agree on the whole with these results.

It may be asked if this is due to the slope of the isobaric surface, which would be lower over a cyclone than over an anticyclone. This is not the case. The difference of pressure over the two regions at a height of 10 km. does not amount to more than 10 mm., while the difference of pressure between 10 and 12 km. is 50 mm.

This excludes the hypothesis that the air in the upper region is an inert isothermal mass consisting always of the same air, lifted up and down by the disturbances in the lower part of the atmosphere.[4] There must be interchange of air in the upper region itself or between the two regions.

The absence of vertical temperature fall implies that general direct convection in the upper region is also absent, but the occurrence of irregu-

[1] *Wozduchoplanawiji i Izsledowaniji Atmosfery*, vol. iii. 1897.
The results obtained by Hermite and Besançon in March 1893 showed a temperature of 21° C. just below 16 km., but the balloon floated for some hours at that height, and in no sense can they be said to have anticipated Teisserenc de Bort's discovery. C.R. cxvi. p. 767.

[2] Séances, 1899, &c., *Annuaire de la Société Météorologique*, 1902.

[3] *Ergebnisse Aëronautischen Obs., Berlin*, May 1902; *Berl. Ber.*, 1902.

[4] But see Shaw's deduction, *infra*, p. 108.

larities in occasional ascents indicates that there is in places limited convection, and the considerable inversion of temperature frequently found at the dividing surface suggests that there may be oblique convection similar to that for anticyclones in the lower atmosphere. Any fall of temperature arising from such convection would tend to disappear owing to the effect of radiation. In general, however, interchange of air in the upper region would be mainly by advection and the two regions might be appropriately named advective and convective regions,[1] expressing the characteristic difference between them.

The height of the dividing surface will be denoted by H_c, and the temperature at this height by T_c.

Although H_c varies with the latitude, the observations available are insufficient to enable an accurate expression for the relation to be obtained. Teisserenc de Bort [2] found from simultaneous ascents at Trappes and at Kiruna on the Arctic circle that the value of H_c was practically the same for the two places, but the value of T_c was slightly lower for Kiruna.

Towards the equator, on the other hand, the value of H_c is considerably greater than for temperate latitudes. Rotch and Teisserenc de Bort failed to reach it over the Atlantic with balloons reaching 15 km. It has been reached, according to Assmann,[3] by a German expedition which sent up balloons from a steamer on Lake Victoria Nyanza in 1908. Two of these reached heights of 17 and 19·8 km., and both entered an isothermal region, the temperature in which was lower than that found in temperate latitudes. The lowest temperature was −84° C. or 189° A.

The following table gives the mean values of H_c and T_c for certain places determined from the monthly mean values. The thirteen stations are those enumerated above and Guadaljara, Milan and Pavia, and Hamburg :—

—	Mean of 13 Stations	Munich	England	Strass-burg	Paris	Pav-lovsk	Kout-chino	Milan	Vienna	Berlin
H_c . .	10·6	10·9	10·8	10·8	10·4	9·6	10·6	10·7	10·2	10·7
T_c . . .	16°	16°	18°	15°	18°	18°	14°	17°	15°	16°
No. of Cases	336	53	32	67	57	28	18	25	24	32
Latitude .	—	48°	52°	49°	49°	60°	56°	45°	48°	52°

There is very little variation for places in Europe between lat. 45–55° : the more Continental stations give a slightly lower value for T_c than the others. For Pavlovsk the value of H_c is 1 km. below the average for the other stations and the value of T_c is 2° above the average value.

The results indicate that there must be a comparatively rapid increase in H_c in crossing the limit of the trade-wind region, and it appears probable that the equatorial currents and the trade winds form a closed system without very much interchange of air with higher latitudes.

Schmauss [4] has pointed out that the value of H_c is greater in summer than in winter.[5] The following table shows the annual variation in H_c, T_c

[1] The upper region has been usually described as 'the isothermal layer.' Recently T. de Bort has introduced the terms 'stratosphere,' 'troposphere,' to denote the upper and lower regions.

[2] *Compt. rend.*, **145**, 1907; *Met. Zeit.*, 1907.

[3] *Quart. Journ. Royal Met. Soc.*, 1909.

[4] *Registrierballonfahrten*, München, 1908.

[5] Rotch states that in America the conditions are reversed, and the minimum value of H_c occurs in the summer. This is probably due to the inclusion of the large values he found in October in the winter series. *Met. Zeit.*, January 1909.

deduced from the results for the thirteen stations and for Strassburg and Munich separately:—

Annual Variation in H_c.

——	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean of 13 Stations	10·3	10·4	9·1	10·1	10·5	10·7	10·9	11·4	10·4	11·9	10·8	10·1
Number of Cases .	26	22	32	39	31	27	24	61	46	38	25	25
Munich . . .	10·0	10·4	9·2	9·2	11·2	11·0	11·7	12·0	10·3	12·3	11·8	11·4
Number of Cases .	4	3	6	4	2	4	3	11	5	5	2	5
Strassburg . .	10·5	10·6	9·4	9·4	10·6	10·9	10·8	12·3	10·9	11·9	11·0	11·1
Number of Cases .	5	5	5	5	4	5	4	9	8	6	6	5

Annual Variation in T_c.

——	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean of 13 Stations	13	11	16	16	17	20	20	18	22	14	15	14
Munich . . .	14	10	16	19	25	20	15	16	26	9	10	13
Strassburg . .	11	10	16	20	17	17	21	15	23	13	12	10

The values of H_c are plotted in Fig. 1.

The observations are made at the beginning of each month, and the results may be taken to correspond nearly to the 4th of each month. The observations made at the end of July are counted in August, so that the values for August correspond nearly to the last day in July. The most remarkable feature is the depression in the value of H_c in March and September.

The fact that H_c is greatest in October and T_c is greatest in September effectually refutes the hypothesis that the cessation in the fall of temperature is due to any effect either of solar or of terrestrial radiation on the instruments.

The value of T_c is certainly slightly greater during the summer months, but the difference between the mean value for summer and winter is only 6° C. This difference is less than the difference in the mean temperature of the atmosphere up to 10 km. for the corresponding period, and it may well be a real increase in the temperature of the advective region owing to increased radiation from below.

It has been suggested that the cause of the sudden change in the temperature gradient, which would naturally be expected to diminish gradually, is the formation of a veil of Ci. or Ci. S. If this were the case the annual variation in the height of these clouds ought to show the same peculiarities as the annual variation in H_c. The annual variation in the height of Ci., Ci. S., Ci. Cu. is given in Fig. 1. The observations used are those for the international year 1896–97. The curves do not show the very marked minima in March and September which occur in the H_c diagram, but there are indications of a peculiarity of this kind, more pronounced in the Ci. S. and Ci. Cu. curves than in that for Ci. proper. The annual range is about the same as for H_c, 2·5 km. nearly. The actual values of the heights are, however, much less than those of H_c. Thus, while the results point to some common cause for the variation in H_c and in the height of the clouds, they indicate that the formation of clouds is not a usual cause of the sudden fall and change of sign in the temperature gradient.

One of the most remarkable features is the large variation sometimes found in T_c and H_c from one day to the next. This has been most marked in England, and the general agreement in results from different stations

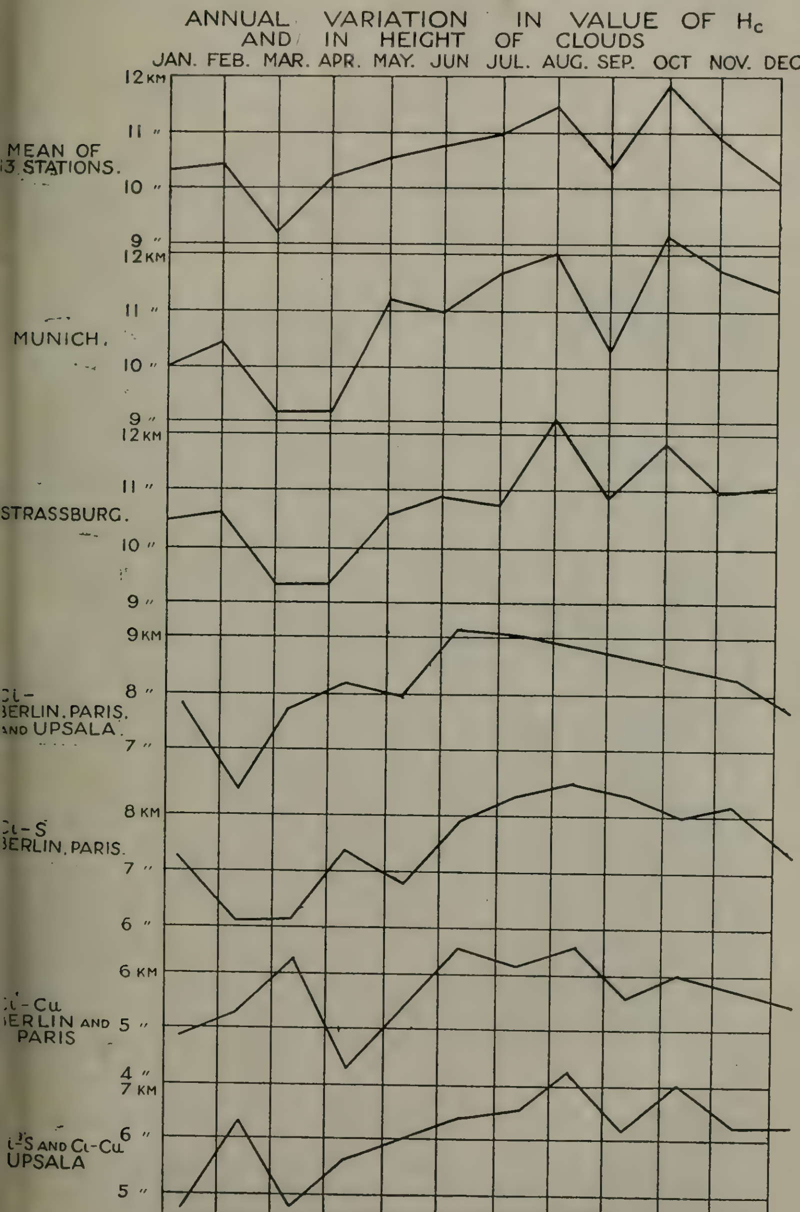

ANNUAL VARIATION IN VALUE OF H_c AND IN HEIGHT OF CLOUDS
JAN. FEB. MAR. APR. MAY. JUN JUL. AUG. SEP. OCT NOV. DEC
MEAN OF 13 STATIONS.
MUNICH.
STRASSBURG.
Ci- BERLIN. PARIS. AND UPSALA.
Ci-S BERLIN. PARIS.
Ci-Cu BERLIN AND PARIS
Ci-S AND Ci-Cu UPSALA
12 KM
11 "
10 "
9 "
8 "
7 "
6 "
5 "
4 "

FIG. 1.

proves that it cannot be attributed to instrumental errors. For example, on April 1, 2, 3, 1908, the values of H_c, T_c v ere

	H	T_c	
April 1	10·5	15°	Manchester
„ 2	12	17°	Pyrton Hill
„ 3	7	24°	Manchester

The result is not surprising, since the English stations are subject to more frequent and rapid changes in the pressure distribution than the Continental stations. But it is nevertheless difficult to see how changes in the convective region can affect T_c and the mean temperature found in the advective region.[1]

The fact that the lowest temperatures occur over the equatorial region suggests that the general nature of the process may be as follows: The cool air in the upper equatorial regions moves Polewards, and in the natural course descends again to feed the trade winds. Owing to the irregularities of the earth's surface, the change of seasons and the very considerable difference between the North and South Hemispheres, the regular process will be disturbed and even in general will not be symmetrical. This will result in encroachments of the equatorial cold air on the advective region of temperate latitudes, and such encroachments will produce anticyclonic regions. The advective atmosphere would be reached there at a higher level and initially at a lower temperature than in the normal or average state; but the temperature would be gradually raised by absorption of thermal radiation to the normal value for that latitude.

The fact that H_c has minimum values in March and September when equatorial temperatures are highest appears at first to be contrary to the idea. But the first effect of the increased equatorial temperature will be to increase the strength of the trade winds,[2] and as at the same time there is in progress a transference of air across the equator to the Southern hemisphere, a transference which can be made only through the upper return current, there will be a deficiency of descending air and the equatorial cold air will encroach less than usual on the Northern advective region. Naturally, if the earth were symmetrical, it would be expected that the process in September would be the reverse of this. But the autumnal transference of air to the Northern Hemisphere will be initially much more intense towards the great Asiatic continental region and, in a less degree, to North America, than to the Atlantic and European area, and the result may well be that the equatorial current again encroaches less than usual on that region. If such is the case it may be expected that the value of H_c over the Asiatic area will not show the September minimum, and that if it occurs over America it will at least be less marked than over Europe. The high value of H_c in October indicates that in that month the encroachment has become more general.

The results of observations made with pilot balloons to heights greater than H_c point to a decrease in wind velocity on entering the advective region.

[1] See, however, Shaw, *Perturbations of the Stratosphere; The Free Atmosphere in the Region of the British Isles*, M.O., 202.

[2] Over the Atlantic the N.E. trade wind is strongest in April, but has a secondary maximum in February. It is weakest in September. The S.E. trade wind is strongest in February, and has a secondary maximum in April. It is lightest in May, and has a secondary minimum in September. See Hepworth, *Brit. Assoc. Reports*, Dublin, 1908, p. 625.

The following table illustrates this :—

Date	Place	H_c	Layer in which Wind Decreased	Decrease in Velocity	Velocity in Advective Region
		km.	km.	m.p.s.	m.p.s.
July 28, 1908	Ditcham	12	11 – 13	18	3
July 29, „	„	13(?)	12 – 13	9	13
July 31, „	„	12·5(?)	11 – 13	6	27
Feb. 6, „	Munich	12	11 – 13	15	18
July 2, „	„	11·6	12 – 16	10	7
Oct. 2, „	„	13·2	11·6–14·7	8	8

On July 31 and September 30, 1908, the velocity was observed up to 12·9 and 13·6 km. respectively, and showed no falling off, but a steady increase. The values of H_c were 13·2 and 13·6 km. There is little doubt therefore that the falling off in velocity is associated closely with the advective region.

On July 28 the maximum wind at Ditcham was 24 m.p.s. from N.N.W., and at Munich on the same day the wind at 12 km. was 21 m.p.s. from N. by W., indicating that the current extended right across the intervening region, just beneath the advective region.

The attempts to furnish a reasonable explanation of the phenomenon on theoretical grounds led to various suggestions. Trabert [1] showed that if there were a decrease of temperature in a horizontal direction in passing eastwards over Europe, and if the air moving eastwards also had a small ascending motion, then the adiabatic fall of temperature would not exist in a vertical direction. It appears probable, however, that the causes which produced a horizontal decrease of temperature in one layer would also produce a similar decrease in the layer above it, and in that case Trabert's effect would vanish.

Fenyi [2] considered the question of the absorption of solar radiation in the upper atmosphere. He concluded that, if the phenomenon were due to this, there must be absorption of dark radiation, since the ultra-violet radiation would be insufficient even if it were all absorbed.

Humphreys [3] pointed out that if the effective radiating power of the earth and atmosphere were the same as that of a black body at temperature T_1, the effect on any radiating and absorbing matter near enough to the earth for the radiating surface to be regarded as an infinite plane would be to keep the matter at a constant temperature such that the radiation from it would be half the radiation from it at temperature T_1. If the radiating matter were such as to admit of the application of Stefan's law, its temperature would be T, where $T^4 = \frac{1}{2}T_1{}^4$.

The observed value of T agrees with the value deduced from this equation by giving T_1 the value estimated by Abbott and Fowle [4] from the value of the solar constant, regard being paid to the proportion of the incident solar radiation which is reflected and does not affect the temperature of the earth.

Gold [5] developed a theory based on the experimental results for atmospheric absorption obtained by Paschen and others. His argument

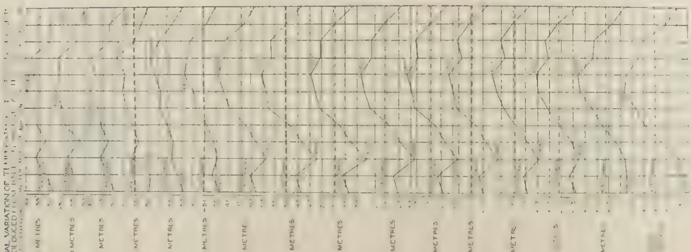
[1] *Met. Zeit.*, 1907. [2] *Ibid.*, 1907.
[3] *Astrophysical Journ.*, 1909.
[4] *Annals of Observatory of Smithsonian Institution*, vol. ii.
[5] *Proc. Roy. Soc. A.*, vol. lxxxii.

rests on the principle that a necessary condition for convection is that in the upper part of the convective system the radiation from any horizontal layer must exceed the absorption by it. He takes the temperature in the convective region to be given with sufficient approximation by the equation $T^n = kp$ where $n=4$ and p is pressure: and represents the radiating power of the atmosphere by $a/(q-p)$, where a and q are constants, in order to allow for the diminution with height arising from the decrease in the amount of water vapour present.[1] He finds that for an atmosphere of uniform constitution the adiabatic state cannot exist to a height greater than that for which $p=\frac{1}{2}p_0$ where p_0 is the surface pressure, because if it extends at any time to a greater height the absorption in the upper part will exceed the radiation. He shows that for the actual atmosphere the adiabatic state can exist to a limited height only, and that if the atmosphere consist of an adiabatic and an isothermal region the adiabatic state must extend to a height greater than 5·5 km., and cannot in general extend to a height greater than 10·5 km. He shows also that the radiation from the lower half of the convective region exceeds the absorption by it, and deduces that its temperature must be maintained by convection from the earth's surface and by condensation of water vapour. It follows also from the theory that if in the upper region the temperature increases with the height the conditions for thermal equilibrium are satisfied if the convective atmosphere extends to a height greater than that for the case of an isothermal upper region—*i.e.*, the limits for H_c are greater than 5·5 and 10·5 km.

Shaw[2] has recently considered the connection between a depression of the lower surface of the advective region and the temperature distribution in that region. He finds that if such a depression is produced artificially or through a disturbance in the convective region, the first effect will be to produce a horizontal difference of temperature in the advective region. If the advective region is initially isothermal it will still be

[1] It has been suggested that the upper limit of the convective region may be also the upper limit of the water vapour atmosphere. But it appears certain that at this upper limit the atmosphere must always be saturated with water (ice) vapour, and that in the advective region the water vapour atmosphere will be such that the difference of vapour pressure between two points will be equal to the weight of the vapour in the intervening column. For the processes of diffusion and of convection of water vapour alone would tend to produce a water vapour atmosphere, in which the amount of vapour present at any height in the convective region would be more than sufficient to produce saturation at that height for the temperature in the actual atmosphere. The only process which prevents the atmosphere being saturated at all heights is the descent of air carrying with it the water vapour it contained at the beginning of the descent, an amount insufficient to saturate it at lower levels. But at the upper limit of the convective region there can be no considerable descent of air from above, and the air arriving there from below will necessarily be saturated, since it must contain sufficient water vapour to saturate it at the lowest temperature to which it has been exposed, *i.e.* T_c. Of course the actual amount of water vapour present is small compared with the amount present near the earth's surface; but a small amount of water vapour is sufficient, at ordinary temperatures at least, to produce considerable absorption of terrestrial radiation, and the absorption extends through a large part of the spectrum of radiation at terrestrial temperatures. In fact, it is probably chiefly due to the presence of this water vapour that it is possible to obtain theoretical results agreeing with the observed facts by using the assumption that the absorption, and therefore also the radiation, is sufficiently extensive to warrant the application of Stefan's law. It follows, also, from this reasoning, that the mean amount of vapour present at any height above the lower cloud level will be at least half the sum of the amount for saturation at that height, and the amount necessary for saturation at the height H_c.

[2] *Perturbations of the Stratosphere*, M.O., 202.



...rating the Report on the Present State of our Knowledge of the Upper Atm...

vertically isothermal, but the be the same for all. Over th He finds that the value of H, height of the 'homog... temperatures. If the increa H, is about 2 km.

IV. (*d*) *Annu*

A question of some intere temperature at different hei the manned balloon ascents no diminution up to 5 km., an a tendency to decrease, the definite conclusions. He giv as the difference between the

Height	Surface	1
Range	[illegible]	[illegible]
No. of Cases		[illegible]

Teisserenc de Bort [2] dedu in 1898–1900 that the rang Taking as the range the di monthly mean temperatures

Height

Range

The following table give monthly mean temperatures Column M gives the number were obtained. The values of the mean temperatures stations :—

Annual

Height	Berlin R	Berlin M	Manned Balloons
Surface	26	12	21
1 km.	15	13	16
2 "	13	12	14
3 "	17	12	15
4 "	[illegible]	12	17
5 "	17	12	
6 "	20	12	
7 "	18	12	
8 "	[illegible]	12	—
9 "	15	12	—
10 "	11	12	
11 "	14	[illegible]	
12 "	[illegible]	12	
13 "	21	8	—
14 "	[illegible]	7	
15 "	[illegible]	6	—

¹ *Wissenschaftliche Luftfah*

vertically isothermal, but the temperature of the vertical columns will not be the same for all. Over the depression the temperature will be raised. He finds that the value of H_c is diminished by 3·5 times the difference of height of the 'homogeneous' stratosphere at the normal and increased temperatures. If the increase of temperature is 20° C., the decrease in H_c is about 2 km.

IV. (*d*) *Annual Variation of Temperature.*

A question of some interest is the magnitude of the yearly variation of temperature at different heights. Berson[1] concluded from the results of the manned balloon ascents that the absolute range showed practically no diminution up to 5 km., and that above that height, although there was a tendency to decrease, the ascents were not numerous enough to warrant definite conclusions. He gives the following values for the range, taken as the difference between the extreme temperatures observed :—

Height	Surface	1	2	3	4	5	6	7	8 km.
Range . .	(31°·6)	29°·7	30°·4	31°·8	32°·2	31°·0	27°·3	25°·0	17°·8 C.
No. of Cases .	—	56	50	40	32	20	11	5	4

Teisserenc de Bort[2] deduced from his observations with ballons-sondes in 1898–1900 that the range decreased considerably with the height. Taking as the range the difference between the extreme values of the monthly mean temperatures he found the following results :—

Height	Surface	5 km.	10 km.
Range	16°·9	14°·6	11°·9 C.

The following table gives the range in degrees C., taken from the monthly mean temperatures, for ten stations, up to a height of 15 km. Column M gives the number of months in the year in which observations were obtained. The values for the ten stations together are the ranges of the mean temperatures and not the mean of the ranges for different stations :—

Annual Range from Monthly Means.

Height	Berlin		Manned Balloons	Paris		England		Pavlovsk		Uccle		Zurich	
	R.	M.		R.	M.	R.	M.	R.	M.	R.	M.	R.	M.
Surface	26	12	21	16	12	19	10	26	12	21	12	19	11
1 km.	15	12	16	17	12	22	10	25	12	18	12	20	11
2 „	13	12	14	17	12	21	10	22	12	19	12	16	11
3 „	17	12	15	16	12	21	10	24	12	20	12	14	11
4 „	16	12	17	17	12	20	10	25	12	22	12	16	11
5 „	17	12	—	19	12	19	10	21	12	25	12	21	11
6 „	20	12	—	21	12	18	10	21	12	26	12	23	11
7 „	18	12	—	22	12	22	10	16	12	29	12	25	11
8 „	18	12	—	23	12	21	10	16	12	26	12	26	11
9 „	15	12	—	19	12	18	10	14	12	24	12	21	10
10 „	11	12	—	16	12	16	10	16	12	17	12	12	8
11 „	14	12	—	18	12	14	10	22	12	12	12	14	8
12 „	19	12	—	20	12	15	10	21	12	13	12	15	6
13 „	21	8	—	19	12	25	9	17	9	18	12	23	5
14 „	25	7	—	18	12	25	9	10	6	15	11	(6)	2
15 „	28	6	—	22	11	25	7	11	5	15	11	(9)	2

[1] *Wissenschaftliche Luftfahrten*, III. [2] *C. R.*, 1900, and *Met. Zeit.*, 1901.

Height	Strassburg		Munich		Vienna		Koutchino		Ten Stations	
	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.
Surface	22	12	25	12	32	12	41	11	21·9	12
1 km.	20	12	22	12	25	12	27	11	16·7	12
2 ,,	18	12	17	12	17	12	24	11	14·0	12
3 ,,	18	12	18	12	15	12	18	11	15·0	12
4 ,,	18	12	21	12	16	12	18	11	16·0	12
5 ,,	20	12	23	12	17	12	19	11	17·2	12
6 ,,	21	12	23	12	17	12	20	11	18·3	12
7 ,,	21	12	23	12	21	12	22	11	19·1	12
8 ,,	21	12	24	12	18	12	23	11	18·5	12
9 ,,	17	12	22	12	18	12	24	11	16·1	12
10 ,,	14	12	16	12	19	12	25	11	12·3	12
11 ,,	16	12	14	12	18	11	18	11	11·2	12
12 ,,	18	12	19	12	19	10	19	11	11·4	12
13 ,,	16	12	16	11	19	8	17	10	13·3	12
14 ,,	16	12	14	8	17	7	15	9	12·2	12
15 ,,	19	12	10	6	13	6	15	6	13·9	12

The range diminishes in the first 2 or 3 km., and afterwards increases to a maximum value at a height of 7–8 km. which is also the height at which the vertical gradient is a maximum. The range then diminishes until the advective region is reached, after which it shows a further slight increase. This last small increase may be due to the effect of solar radiation on the instruments in some ascents, but the values show that there is still a considerable annual variation of temperature even at a height of 15 km.

The following values for the first four components of the annual variation of temperature over Berlin have been deduced from the results of kite and balloon observations made in the five years 1903–07.[1] Time is measured from January 1.

Height.	Temperature.
122 m.	$81°·4 + 9·77 \sin(nt. + 254) + 0·19 \sin(2nt. + 40) + 0·38 \sin(3nt. + 10) + 0·46 \sin(4nt. + 161)$
500 m.	$79°·3 + 8·22 \sin(nt. + 249) + 0·05 \sin(2nt. + 42) + 0·46 \sin(3nt. + 352) + 0·33 \sin(4nt. + 260)$
1000 m.	$77°·0 + 7·28 \sin(nt. + 244) + 0·15 \sin(2nt. + 117) + 0·47 \sin(3nt. + 349) + 0·21 \sin(4nt. + 282)$
1500 m.	$74°·8 + 6·53 \sin(nt. + 243) + 0·24 \sin(2nt. + 195) + 0·35 \sin(3nt. + 24) + 0·46 \sin(4nt. + 18)$
2000 m.	$72°·4 + 6·10 \sin(nt. + 239) + 0·18 \sin(2nt. + 90) + 0·46 \sin(3nt. + 3) + 0·24 \sin(4nt. + 312)$
2500 m.	$70°·4 + 5·88 \sin(nt. + 236) + 0·03 \sin(2nt. + 115) + 0·28 \sin(3nt. + 338) + 0·14 \sin(4nt. + 29)$
3000 m.	$67°·9 + 5·94 \sin(nt. + 237) + 0·17 \sin(2nt. + 204) + 0·53 \sin(3nt. + 285) + 0·12 \sin(4nt. + 131)$

The actual mean monthly temperatures are given in the table :—

Height		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Surface	122 m.	71·8	73·4	76·2	80·1	87·2	89·6	91·0	90·2	86·4	81·4	76·4	72·7	81·38
,,	500 m.	71·5	72·1	73·5	77·4	83·6	85·8	87·3	86·8	84·3	80·5	75·9	72·2	79·32
,,	1,000 m.	70·4	70·1	72·1	74·6	80·4	82·5	84·2	83·6	81·6	78·8	74·5	71·0	76·97
,,	1,500 m.	69·1	68·2	69·9	73·7	77·3	79·4	81·2	80·5	79·2	76·9	72·6	69·5	74·80
,,	2,000 m.	67·3	66·6	67·8	70·0	74·6	76·7	78·4	78·0	77·0	74·4	70·7	68·0	72·44
,,	2,500 m.	65·2	64·6	66·0	68·0	71·9	74·0	76·4	75·5	75·0	72·6	69·2	66·2	70·38
,,	3,000 m.	61·6	62·4	63·9	65·6	69·2	72·2	73·9	72·9	72·2	70·4	66·7	63·8	67·90

[1] *Ergebnisse*, Berlin and Lindenberg.

The following table gives the total number of days in each month on which the observations, used for the calculation, were made :—

—	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Surface	155	141	155	150	155	150	155	155	150	155	150	155
500	155	139	154	150	155	150	155	155	150	155	150	154
1,000	146	133	150	146	154	150	151	152	148	152	147	150
1,500	115	98	110	122	132	128	134	132	129	134	124	120
2,000	79	73	76	89	97	100	91	111	109	112	94	83
2,500	49	48	48	57	67	71	66	85	85	84	77	60
3,000	24	29	29	30	39	55	50	55	65	60	55	36

The surface observations for 1903, 1904, January–March 1905, were made at 40 m. They have been reduced to 122 m. by taking for each of the 27 months the mean gradient observed in that month between 40 m. and 500 m.

The outstanding features of the results are a steady decrease in the amplitude and in the phase of the whole year term. The minimum temperature occurs near January 15 at the surface, while at 2,000 m. it does not occur until February 1.

The results for 3,000 m. are unduly influenced by the fact that the observations at that height in January 1907 were made during a very cold period, and probably diminished the mean value for that month below its true value. The effect would be to increase the phase for that height.

The amplitude at 2·5 km. is only $\frac{3}{5}$ of its surface value, but it does not appear to decrease above this height.

Hann[1] gives the following values for the amplitude of the yearly variation on mountain peaks and well-exposed places :—

Place	Altstätten	Trogen	Gäbris	Rigikulm	Säntis	Sonnblick
Height	460 m.	880 m.	1,250 m.	1,790 m.	2,500 m.	3,100 m.
Range	19°·4	17°·1	15°·5	14°·4	14°·1	14°·5 C.

These values show the same general decrease up to 2·5 km. as those found for the free atmosphere, but they are in all cases 2°–3° C. greater than for the free atmosphere.

The four components have been given to show the comparative regularity of the third both in amplitude and phase, compared with the second and fourth, the latter of which appears to be merely the result of accidental irregularities.

The result appears interesting and worth investigation, because there is a similar period in the velocity of the centres of anticyclones.

The following expression for the annual variation of this velocity in m.p.s. in America has been deduced from results given by Herrmann :[2]

$$V = 11{\cdot}4 + 1{\cdot}30 \sin (nt + 68^\circ) + 0{\cdot}12 \sin (2nt + 138^\circ)$$
$$+ 0{\cdot}31 \sin (3nt + 18^\circ) + 0{\cdot}09 \sin (4nt + 78^\circ).$$

Here the third component has an amplitude more than double that of the second, and treble that of the fourth, and its phase agrees very nearly with the corresponding term in the variation of temperature. This implies that when anticyclones are moving rapidly in America, the mean temperature over Berlin is above the normal value.

[1] *Lehrbuch*, p. 105.

[2] *Monthly Weather Review*, April 1907.

The velocity of anticyclones in Europe has not been dealt with since 1887 when Brounow [1] gave results based on ten years' observation. These results give

$$V = 7{\cdot}7 + 0{\cdot}32 \sin(nt + 85^\circ) + 0{\cdot}31 \sin(2nt + 146^\circ) + 0{\cdot}76 \sin(3nt + 216^\circ) + 0{\cdot}56 \sin(4nt + 178^\circ).$$

The number of observations was considerably less than that used by Herrmann, but the third component is still greater than the second and fourth. The phase is nearly opposite to that for America.

This implies that in rapidly moving anticyclones the mean temperature up to 3 km. is below the normal. The result may be compared with Hanzlik's deduction that a rapidly moving anticyclone remains cold.

The annual variation for heights up to 15 km. has been calculated from the ascents of registering balloons.

The following table gives the results when the temperature is expressed in the form :—

$$T = T_0 + P_1 \sin(nt. + A_1) + P_2 \sin(2\,nt. + A_2) + \text{—}$$

the time being measured from January 1.

Height.	T_0	P_1	A_1	P_2	A_2	P_3	A_3
		°C	°	°C	°	°C	°
1 km.	77·0	8·3	245	0·55	39	0·49	307
2 ,,	72·8	6·5	235	0·75	50	1·35	321
3 ,,	67·6	6·1	232	0·87	77	1·25	347
4 ,,	61·8	6·4	231	1·28	73	1·55	344
5 ,,	55·6	6·7	232	1·20	66	1·43	354
6 ,,	48·7	7·3	231	1·51	72	1·66	355
7 ,,	41·5	7·5	231	1·52	68	1·85	358
8 ,,	34·1	7·6	232	1·32	77	1·77	359
9 ,,	27·3	7·0	231	1·06	35	1·46	361
10 ,,	22·3	5 6	234	1·26	333	0·98	356
11 ,,	19·0	4·7	246	1·6	314	0·85	362
12 ,,	18·3	4·6	259	1·4	319	0·2	218
13 ,,	19·1	4·1	275	2·1	354	1·0	326
14 ,,	19·1	4·0	272	1·8	22	1·0	328
15 ,,	19·2	4·4	272	2·0	356	1·1	317

The results agree with those deduced above from kite observations in showing a decrease in amplitude and phase of the whole year term in the first 3 km. But at greater heights the amplitude increases, and the phase remains constant up to 8–9 km., after which the amplitude again diminishes while the phase increases. Thus, at 13 km., the maximum and minimum temperatures, arising from the whole year term, occur at the end of June and December respectively, while in the layers 4–9 km. the corresponding times are the second weeks in August and February. The third component shows great regularity in phase, and its amplitude increases and decreases with the whole year variation until a height of about 12 km. is reached, when the amplitude vanishes and the phase changes by nearly 180°, returning gradually towards the value it has near the surface.

The second component increases with the height up to 7 km., and afterwards diminishes for 2 km. It then increases again, and in the upper layers is half as big as the whole year variation.

The following tables give the mean temperatures for each month at different heights and the number of observations from which they are calculated. The results are plotted in the diagram Plate II., and Fig. 2.

[1] *Repertorium für Meteorologie*, 1887.

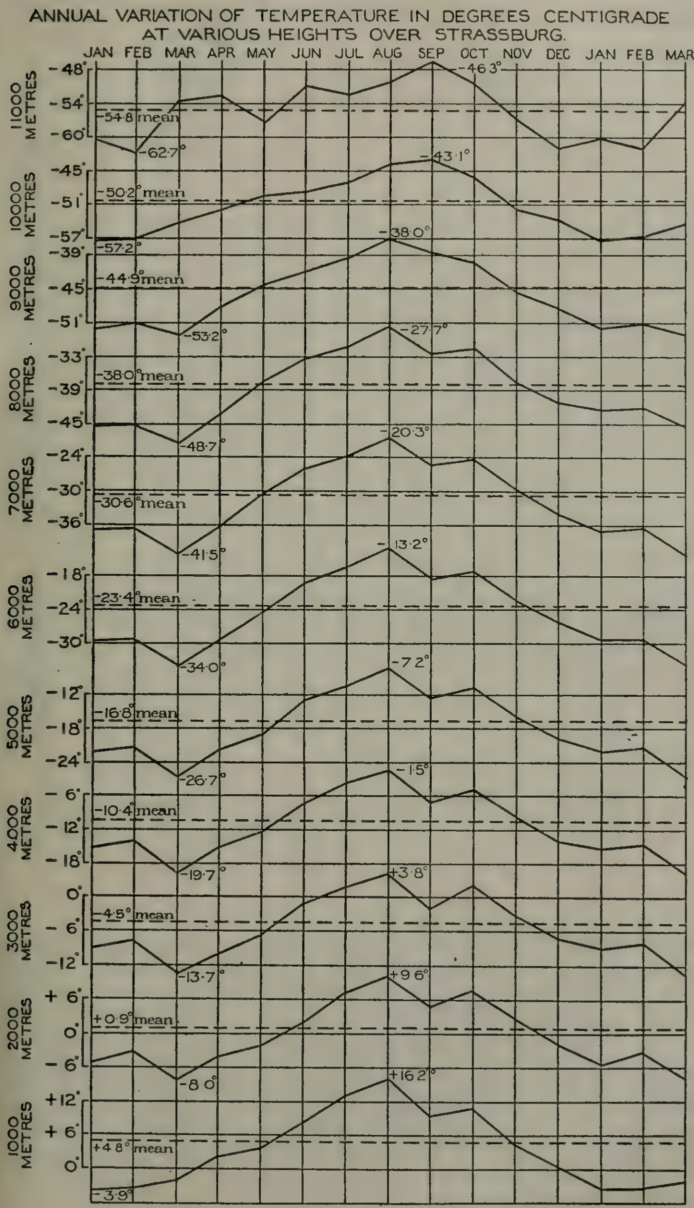

ANNUAL VARIATION OF TEMPERATURE IN DEGREES CENTIGRADE
AT VARIOUS HEIGHTS OVER STRASSBURG.
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
11000 METRES
-48°
-54°
-60°
-46.3°
-54.8 mean
-62.7°
10000 METRES
-45°
-51°
-57°
-43.1°
-50.2° mean
-57.2°
9000 METRES
-39°
-45°
-51°
-38.0°
-44.9° mean
-53.2°
8000 METRES
-33°
-39°
-45°
-27.7°
-38.0° mean
-48.7°
7000 METRES
-24°
-30°
-36°
-20.3°
-30.6° mean
-41.5°
6000 METRES
-18°
-24°
-30°
-13.2°
-23.4° mean
-34.0°
5000 METRES
-12°
-18°
-24°
-7.2°
-16.8° mean
-26.7°
4000 METRES
-6°
-12°
-18°
-1.5°
-10.4° mean
-19.7°
3000 METRES
0°
-6°
-12°
+3.8°
-4.5° mean
-13.7°
2000 METRES
+6°
0°
-6°
+9.6°
+0.9° mean
-8.0°
1000 METRES
+12°
+6°
0°
+16.2°
+4.8° mean
-3.9°

FIG. 2.

shows similar results up to 11 km. for Strassburg. The monthly temperatures correspond to about the 5th of each month, but those for August to July 30.

Mean Temperatures for each Month (200 +). (*Ten Stations.*)

Height	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Surface (about 200 m.)	69·0	71·4	71·7	78·1	83·7	86·6	90·9	89·9	85·9	84·5	75·9	72·0
1 km.	70·0	69·7	70·6	73·6	78·2	81·8	85·7	86·4	81·3	81·3	75·0	70·5
2 ,,	67·6	69·2	66·2	68·3	72·3	76·4	79·6	80·2	76·2	77·2	73·6	66·9
3 ,,	63·6	64·6	59·7	63·2	67·4	71·1	73·4	74·7	70·5	72·2	68·2	62·5
4 ,,	58·0	59·5	53·1	57·2	60·1	66·1	67·8	69·1	64·9	66·5	62·5	56·5
5 ,,	51·6	53·0	46·1	50·6	53·8	60·2	61·7	63·3	59·5	60·3	55·8	50·0
6 ,,	44·5	45·9	38·5	43·6	47·1	53·8	55·6	56·8	53·3	53·3	49·1	43·0
7 ,,	37·0	39·1	30·8	36·2	39·9	46·8	48·3	49·9	46·3	46·4	41·8	35·4
8 ,,	29·0	31·0	23·7	28·8	32·8	40·0	40·7	42·2	39·2	39·2	34·0	28·8
9 ,,	22·1	24·5	19·1	22·7	25·9	31·7	33·0	35·2	32·9	32·8	26·3	22·6
10 ,,	16·5	19·4	17·8	19·0	21·4	25·2	25·7	28·8	28·0	26·8	21·3	17·8
11 ,,	13·4	15·6	17·3	16·9	19·3	21·9	21·3	23·6	24·6	21·7	17·2	13·8
12 ,,	13·5	12·8	19·2	17·3	19·4	20·6	22·6	21·5	24·2	18·0	15·9	13·4
13 ,,	15·3	18·0	20·0	17·3	20·2	21·0	23·7	22·0	23·1	16·4	16·9	10·4
14 ,,	16·1	17·4	20·0	15·1	20·6	21·7	24·2	22·0	22·5	16·0	16·8	12·0
15 ,,	14·8	17·0	20·7	17·0	20·4	21·2	23·9	21·1	22·1	15·7	15·8	10·0
Number of Observations in each Month at each Height.												
Surface	33	28	25	43	33	27	30	67	38	38	33	33
1 km.	34	31	26	45	34	29	33	66	42	42	32	32
2 ,,	32	26	25	41	32	25	26	65	36	41	32	30
3 ,,	32	26	25	41	32	25	26	65	36	41	32	30
4 ,,	32	26	25	41	30	25	26	65	36	41	32	30
5 ,,	32	26	25	41	30	25	26	65	36	41	32	29
6 ,,	32	26	25	41	30	25	26	65	36	41	32	29
7 ,,	32	26	25	39	31	25	25	65	36	41	32	29
8 ,,	32	26	25	38	31	25	24	63	35	40	32	27
9 ,,	31	25	24	38	31	25	24	61	35	36	31	27
10 ,,	30	21	23	34	28	25	24	60	34	36	30	26
11 ,,	27	19	19	31	26	21	24	59	32	34	30	24
12 ,,	21	15	14	23	24	17	21	48	26	33	27	20
13 ,,	17	12	10	18	21	16	16	43	21	30	23	13
14 ,,	13	10	8	13	17	13	7	34	19	26	20	9
15 ,,	5	6	7	6	13	9	7	18	13	17	18	7

The principal feature in the diagrams is the very marked minimum in March and the similar though less marked effect in September. Above 10 km. the conditions are reversed and the minima are replaced by maxima. A similar peculiarity, with which this is indeed connected, was found in the height and temperature at which the advective region was encountered, and an attempt was made to connect it with the general circulation of the atmosphere. The effect cannot be explained as due to a mere retardation in the time of occurrence of the minimum temperature, because the phase of the annual term shows that this retardation reaches its full value at a height of about 3 km., while the depression in March increases in intensity up to 8 km., and the minimum in September flatly contradicts such an hypothesis.

It may be suggested that the pressure distribution at the time at

which the ascents in these months were made, was accidentally peculiar for the five years of observation.

The following table gives the mean pressure at Strassburg for each month on the days of ascents during the five years, and for comparison the mean pressure at Aachen [1] from the records for 1896–1903 :—

Mean Pressure (700 + *mm.*).

——	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Strassburg (140 m.) .	54	55	49	49	53	51	51	51	49	50	50	48
Aachen (169 m.) . .	49	47	44	46	46	47	47	47	47	46	48	45

The differences in pressure are practically no greater than are to be accounted for by the ordinary yearly variation. Of course the same causes which affected the value of H_c and the mean temperature of the upper air would also affect the pressure. The possibility of such accidental peculiarities, however, emphasises the need for weekly ascents at one or two selected stations to fill up the large gaps between successive international ascents.

IV. (*e*) *Diurnal Variation of Temperature.*

Clayton concluded from a discussion of kite ascents made at Blue Hill that the most marked feature in the diurnal temperature variation in the free atmosphere was the increase in the semi-diurnal term, and the vanishing and reappearance with changed phase of the diurnal term in the first 1000 m. Wundt,[2] using observations made at Hald, in Jutland, obtained results for 1,200 m. from which the following expression for the variation has been calculated—

$$T = T_0 + 0{\cdot}55 \sin(nt + 248^\circ) + 0{\cdot}05 \sin(2nt + 349^\circ),$$

time being measured from midnight and the amplitudes being expressed in degrees C.

For the autumn of 1902, his results, which he regards as more trustworthy than the general means, give

$$T = T_o + 0{\cdot}35 \sin(nt + 229^\circ) + 0{\cdot}13 \sin(2nt + 217^\circ).$$

Gold [3] found the following values for 1,000 m. from an analysis of the kite and balloon observations made over Berlin and Lindenberg in 1903–07 :—

$$T = T_s - (4{\cdot}40 \pm 0{\cdot}08) + (0{\cdot}87 \pm 0{\cdot}13) \sin(nt + 197^\circ)$$
$$+ (0{\cdot}14 \pm 0{\cdot}10) \sin(2nt + 123^\circ).$$

where T_s is the mean surface temperature at Potsdam (40 m.). This agrees with Wundt's results in making the amplitude of the semi-diurnal term small, but differs from them considerably in the amplitude of the diurnal term and in the phases of both terms.

A similar result was found when only those observations were used in which the observed wind at 1,000 m. was not less than 8 m.p.s.

[1] *Met Zeit.*, 1906, p. 91. [2] *Ibid.*, 1908.
[3] *Nature*, July 1, 1909.

The value was—

$$T = T_s - (3{\cdot}97 \pm 0{\cdot}15) + (0{\cdot}84 \pm 0{\cdot}23) \sin (nt + 173°) + (0{\cdot}35 \pm 0{\cdot}15) \sin (2nt + 102°),$$

and the agreement between the diurnal terms in the two cases proves that the results are not influenced to any considerable extent by solar radiation. The variation at 2 km. was found to be considerably less. It is approximately given by

$$T = T_s - (9{\cdot}84 \pm 0{\cdot}23) + (0{\cdot}64 \pm 0{\cdot}31) \sin (nt + 270°) + (0{\cdot}25 \pm 0{\cdot}23) \sin (2nt + 72°).$$

The variation of the temperature in the free atmosphere is theoretically connected with the variation of pressure. Mountain observations[1] lead to the conclusion that the amplitude of the diurnal variation of pressure diminishes with height, vanishes and reappears with a change of phase of 180°. The semi-diurnal term, on the other hand, has its amplitude roughly proportional to the pressure, and its phase diminishes gradually with increasing height.

If these conditions hold also in the free atmosphere, the phases of the diurnal variations of pressure and temperature ought to differ by 180° in the lower layers and ought to agree after the change in the pressure variation, *i.e.*, the phase of the variation of temperature ought not to change materially from its surface value. The observations are in fair agreement with this conclusion.

The phases of the semi-diurnal variations of temperature and pressure ought to differ at the surface by 90° nearly, the latter (pressure) being the larger. In the upper layers this difference ought to diminish.

The phase of the semi-diurnal variation of temperature found above is subject to a considerable probable error, but the results indicate a tendency in it to approach the value found for the phase of the pressure variation from mountain observations. Thus at Kew the phases actually differ by about 100°, while the phase at 1,000 m. differs by only 20°–30° from the phase of the variation of pressure observed at 1,000 m. in the Alps.[2] The results for the temperature are, however, not sufficiently accurate to warrant conclusions as to the variation of pressure in the free atmosphere being drawn from them.

V. *Wind.*

The first attempt to discover the way in which the velocity of the wind changed with the altitude in the free atmosphere by the use of recording instruments appears to have been made by Archibald, whose results were communicated to the British Association at Montreal twenty-five years ago. He concluded that the velocities V, v, at heights H and h above the surface were connected by the equation

$$V/v = (H/h)^x$$

where x diminished with height, but tended to a value nearly equal to $\frac{1}{4}$.

[1] On the Pic du Midi, 2,860 m., the daily variation of pressure is given in mm. by

$$\Delta p = 0{\cdot}19 \sin (nt + 180°) + 0{\cdot}25 \sin (2nt + 124°)$$

and that of temperature by

$$\Delta T = 1{\cdot}8 \sin (nt + 251°) + 0{\cdot}6 \sin (2nt + 80°).$$

Met. Zeit., 1908. See also *Hann. Lehrbruch*, p. 605.

[2] *Hann. Lehrbuch*, p. 605.

Berson [1] found the following values for the ratio of the mean velocity in layers 500 m. thick to the mean wind for the day at Potsdam. The latter was 5·5 m.p.s :—

Layer	0–0·5	0·5–1·0	1·0–1·5	1·5–2·0	2·0–2·5	2·5–3·0	3–4	4–5	above 5 km.
Ratio . .	1·77	1·82	1·85	1·95	2·08	2·16	2·45	3·05	4·46
Ratio (2) .	—	1·00	1·02	1·07	1·14	1·19	1·35	1·68	2·45
No. of Cases	54	54	55	49	41	38	36	19	10

The ratio (2) is formed with the velocity in the layer 0·5–1·0 as standard. The results show a very slow increase up to 2–3 km., after which the change takes place more rapidly. It appears probable that the values up to 3 km. are those appropriate to the pressure distribution at the surface, and indicate that the ratio of the gradient of pressure to the density remains nearly constant up to that height. The larger values in the upper layers show that the intensity increases with height, which is in accordance with the observations of temperature, since these show that the places with higher pressure have also higher temperature in the upper air.

Gold [2] showed from a consideration of kite observations that the major part of the increase in the first 2,000 m. took place in the layers immediately above the surface. For Berlin 75 per cent. of the total increase occurred in the first 160 m.

He found, too, that the velocity increased up to 500 m. almost without exception, but that at greater heights numerous cases occurred where the velocity decreased as the height increased. Thus at Oxshott, between 500 and 1,000 m. the velocity decreased in eight cases, remained constant in seventeen cases, and increased in twenty-three cases out of a total of forty-eight, while at Blue Hill the corresponding numbers were seven, four, and ten out of a total of twenty-one. The change depends on the direction of the wind. Both at Oxshott and Berlin the velocity almost invariably decreased between 1·5 and 2 km. in the case of S.E. winds, while S.W. winds showed the greatest increase near the surface. It was also found that the kite observations over Berlin furnished conclusive evidence that the wind at 1,000 m. altitude agreed both in magnitude and direction with the theoretical velocity deduced from the condition for steady horizontal motion along the isobars, viz.—

$$\frac{(\omega\, r \sin\lambda \pm v)^2}{r} = \frac{1}{\rho}\frac{\partial p}{\partial r} + \frac{(\omega\, r \sin\lambda)^2}{r}$$

where p is pressure, ρ density, v velocity of the air, λ is latitude, ω the angular velocity of the earth about its axis, and r the radius of curvature of the path of the moving air.

Egnell [3] deduced from the observations of clouds that the velocity increases with the height, so that it remains nearly inversely proportional to the density, *i.e.*, the velocity V is given by $V = V_o\rho_o/\rho$, where ρ is density and V_o, ρ_o are the values of V and ρ near the surface.

The law appears to agree moderately with the observations from pilot balloons. The following table gives the values of $V\rho$ in arbitrary units

[1] *Wissenschaftliche Luftfahrten*, III.
[2] *Barometric Gradient and Wind Force*, M.O., 190.
[3] *Comptes rend.*, 1903; *International Cloud Observations.* Trappes.

(metres per sec. × pressure in metres × T_o/T) deduced from ten sets of observations at Munich[1] of which seven reached 12 km :—

Height . . .	1	3	5·5	8	10·5	12 km.
$V\rho$ . . .	50	48	45	53	45	37

Observations made by Cave[2] in July 1908 furnish in the same units at the same heights the following values :—

$V\rho$ . . .	34	55	59	65	50	43
$V\rho$ (May 1909)[3] .	85	54	36	36	33	19

The second row gives values from seven ascents in May 1909.

The law implies that the mean gradients of pressure have the same value in the upper air as near the surface, and this can be the case only if the mean temperature over high pressure is greater than it is over the low pressure, *i.e.*, if the horizontal gradients of pressure and temperature are in the same sense. It was seen from the results for temperature that this was the case. It remains to be seen if the observed difference of temperature is sufficient to make the gradient of pressure constant.

If p and $p + \delta\, p$ are the pressures at two places at the surface, then the corresponding pressures at a height z are pe^{-u}, $(p + \delta\, p)\, e^{-(u+\delta u)}$ where $u = \int \frac{g\, dz}{k\, T} = \int \frac{T_o\, d\, z}{H\ T}$, T being temperature, and H the height of the homogeneous atmosphere, 8 km. nearly.

If the difference of pressure is the same as at the surface

$$e^{-u}\, \delta\, p - p\, e^{-u}\, \delta\, u = \delta\, p, \text{ i.e., } \delta\, p = -\, p\, e^{-u}\, (1 - e^{\ \ u})^{-1}\, \delta\, u.$$

But

$$\delta\, u = -\int \frac{T_o\, dz\ \delta\, T}{H\ T^2} = -\, t_o \int \frac{T_o\, dz}{H\ T^2}$$

where t_o is approximately the mean value of δ T.

Put $T = T_o\ (1 - \alpha\, z)$ and $\alpha\ H = \frac{1}{6}$ corresponding to a constant vertical fall of temperature at a rate of 5°·7 C. per km.

Then $u = -\,(\alpha\ H)^{-1} \log\, (1 - \alpha\, z)$

$\delta\, u = -\, t_o\, (\alpha\ H)^{-1}\, (1 - \alpha\, z)^{-1}$

$e^{-u} = (1 - \alpha\, z)^6$

The condition cannot be satisfied exactly at all heights with such a distribution, but if t_o be determined so that it is satisfied at a height H, say, it will be approximately true for intermediate heights, and the value of t_o will indicate if the condition is likely to be satisfied, regard being paid to the results of observations.

If $z = H$, $\alpha\ H = \frac{1}{6}$, $T_o = 273$

the condition $\delta\, p = p\, e^{-u}\, (1 - e^{-u})^{-1}\, \delta\, u$ becomes

$$t_o = \frac{74\ \delta\, p}{p}.$$

Thus if $\delta\, p = 20$ mm., $t_o = 2°$ C nearly.

Now the actual mean difference in temperature up to 8 km. between regions where pressure > 770 mm. and regions where it < 750, is approximately 4° C. or practically double the amount necessary to make $V\,\rho$ constant. The value of $V\,\rho$ ought, therefore, to be greater at 8 km. than near the surface. The results indicate that this is the case, and they show, further, that $V\,\rho$ diminishes at greater heights. But this is entirely in accordance with the results for temperature, which showed that δ T,

[1] *Registrierballonfahrten*, 1907–08. [2] *Quar. Jour. R. Met. Soc.*, 1908.
[3] *Weekly Weather Report*, 1909.

and therefore also t_o and δp diminished above a height of 8 km. Of course, as long as δ T remains positive $\delta p/\rho$ will increase, and therefore V will increase. But the results for temperature show that δ T is positive up to 10 km., after which it becomes negative. The observations of temperature and wind are therefore in general agreement, indicating an increase in V ρ up to 8 km. and an increase in V up to 10 km., with a rapid decrease of both at greater heights.

The direction of the upper wind usually veers from that at the surface, *i.e.*, if the wind is W. at the surface, the upper wind comes from some point N. of W. This is partly due to the fact that surface friction opposing the motion makes the steady state one in which the direction of the wind is between that of the gradient and the isobars. The smaller the friction, the closer does the direction for the steady state approach that of the isobars.

The following values for the rotation of the upper wind from that at the surface are deduced from Berson's results :—

Height . . .	0·5	1	1·5	2	2·5	3	4	5 km.
Rotation . .	8°	15°	21°	28°	35°	39°	40°	43°
No. of Cases .	58	58	58	51	43	39	35	22

In comparing these results with those obtained from kites it is to be remembered that a balloon does not rise vertically, but is carried along by the moving air and partakes of any natural curvature of path this may have in its horizontal progress.

Similar results found by White, Pring and Petavel[1] show a smaller increase between 1 and 1·5 km., after which the increase is rapid.

Height . . .	0·5	1	1·5	2	2·5 km.
Rotation . .	11°	18°	20°	30°	40°

The authors do not state if these results are the mean values of the rotation irrespective of sign or not.

The following values have been found for the deviation up to 3 km. from the observations made in England in 1906–07–08.[2] The values are the means of the individual cases, rotation in a clockwise direction (veering) being counted +. The values are arranged according to the direction of the surface wind, S.W. winds being counted W. and so on. Only those observations are used in which the wind at 1,000 m. was not less than 5 m.p.s. The values of R are the angles made by the upper wind with the surface wind.

Deviation of the Upper Wind in England.

(R rotation, N number of cases.)

Heights	0·5 km.	1·0 km.	1·5 km.	2·0 km.	2·5 km.	3·0 km.
			Winter (October–March).			
W. R. .	15°	22°	22°	19°	18°	17°
W. N. .	76	76	41	14	5	4
N. R. .	6°·5	13°·5	12°	10°	−5°	0°
N. N. .	37	37	22	10	4	2
E. R. .	18°	25°	17°	19°	22°	27°
E. N. .	37	37	18	10	7	5
S. R. .	16°	26°	32°	36°	37°	45°
S. N. .	61	61	41	23	13	11

[1] *Quarterly Journal R. Met. S.*, 1908.

[2] *Weekly Weather Report.* See also Köppen's *Three Years' Simultaneous Kite Ascents at Berlin, Hamburg, Pavlovsk.* This publication was not available until after the present Report was printed.

Deviation of the Upper Wind in England—continued.
(R rotation, N number of cases.)

Heights		0·5 km.	1·0 km.	1·5 km.	2·0 km.	2·5 km.	3·0 km.
				Summer (April–September).			
W.	R.	5°·5	9°·5	11°	13°	6°·5	7°
	N.	133	133	93	55	26	19
N.	R.	2°	3°	−4°	−6°	−2°	−19°
	N.	48	48	29	20	12	9
E.	R.	12°	19°	21°	33°	41°	18°
	N.	39	39	31	20	14	11
S.	R.	12°	26°	32°	41°	45°	55°
	N.	67	67	41	19	11	10
				Year (Numbers = sums of Winter and Summer).			
W.		9°	14°	14°·5	14°	8°	8°
N.		4°	8°	3°	−1°	−3°	−15°
E.		15°	22°	20°	28°	35°	21°
S.		14°	26°	32°	38°	41°	50°
Mean of all cases		10°	17°	18°	20°	21°	20°
Mean of yearly means		10°·5	17°·5	17°·4	19°·8	20°·3	16°
Total N.		300	298	269	202	142	102

Similar results from Berlin (Lindenberg) for 1906 are as follows [1] :—

Heights		0·5 km.	1·0 km.	1·5 km.	2·0 km.	2·5 km.	3·0 km.
				Winter.			
W.	R.	25°	31°	31°	31°	33°	31°
	N.	76	75	59	39	26	18
N.	R.	17°	20°	23°	22°	13°	29°
	N.	18	18	15	12	8	5
E.	R.	36°	39°	45°	48°	53°	53°
	N.	27	27	26	20	15	12
S.	R.	43°	50°	53°	55°	57°	50°
	N.	55	55	53	42	33	23
				Summer.			
W.	R.	10°	13°	15°	10°	15°	14°
	N.	64	63	62	44	41	25
N.	R.	10°	15°	18°	18°	17°	23°
	N.	24	24	22	18	14	9
E.	R.	17°	18°	28°	41°	34°	7°
	N.	22	22	19	15	7	3
S.	R.	18°	28°	27°	27°	37°	34°
	N.	14	14	13	12	8	7
				Year (Numbers = sums of Winter and Summer).			
W.		18°	23°	23°	20°	23°	22°
N.		13°	17°	20°	20°	15°	25°
E.		27°	30°	38°	45°	46°	44°
S.		38°	46°	48°	49°	53°	46°
Mean of all cases		23°	29°	31°	32°	34°	33°
Mean of yearly means		24°	29°	32°	34°	34°	34°
Total N.		498	498	316	171	92	71

These results show how much the rotation depends on the wind direction and on the situation. At both places S. winds show a greater rotation

[1] *Ergebnisse der Arbeiten des Aëron. Obs.* The observations after April 1905 were made at Lindenberg, which is some distance from Berlin itself.

and a more regular increase than winds from other directions. This is probably due, in part at least, to the fact that the general drift of the upper air is from W. to E. The rotations for Berlin are in nearly all cases greater than in England, but S. winds in summer form an exception. The difference in the upper layers is greatest in the case of N. winds which back slightly in the upper air in England, both in winter and in summer.

The rotation is larger in winter than in summer, indicating that in the latter season convection is more vigorous in equalising the wind in the lower layers. The departures of the wind at higher levels from the direction at 500 m. show that this must be the case since these departures tend to be slightly larger in summer than in winter. S. winds again form an exception and have total rotations slightly larger in summer than in winter in England.

The same observations were used to obtain the increase of the velocity with height.

The following table gives in metres per second the mean observed surface wind and the mean excess of the observed wind at each height above the surface wind at the time of observation. The number of observations in England is slightly less than before because in some cases the direction only was observed at ground level.[1]

Increase in Wind Velocity.

B = Berlin, E = England. N = number of observations for England.

Heights		Surface	0·5 km.	1·0 km.	1·5 km.	2·0 km.	2·5 km.	3·0 km.
				Winter.				
W.	B.	7·5	7·8	8·0	8·0	8·7	9·6	10·5
	E.	5·9	7·2	9·6	10·5	10·8	—	—
	N.	59	59	59	32	7	—	—
N.	B.	5·8	3·8	4·1	5·2	5·7	6·8	7·2
	E.	5·5	5·3	5·8	7·5	7·2	11·8	14·4
	N.	30	30	30	16	6	2	2
E.	B.	5·6	5·4	5·7	5·4	5·8	5·3	5·5
	E.	6·3	6·3	7·2	6·6	6·9	4·2	2·8
	N.	37	37	37	18	10	7	5
S.	B.	5·9	7·5	7·2	7·7	7·7	9·4	10·0
	E.	4·9	6·4	7·8	8·2	7·1	5·8	7·0
	N.	50	50	50	29	15	9	7
				Summer.				
W.	B.	6·2	4·5	6·1	6·3	6·6	7·6	8·2
	E.	5·9	5·3	6·9	8·3	8·5	9·1	8·7
	N.	107	107	107	67	38	26	11
N.	B.	4·9	2·9	3·9	4·3	3·8	3·9	5·9
	E.	5·8	4·1	5·3	5·1	4·5	4·8	8·4
	N.	39	39	39	21	14	7	4
E.	B.	5·2	2·5	3·4	3·6	3·9	4·4	9·3
	E.	5·4	3·5	4·4	4·3	5·1	5·6	6·2
	N.	33	33	33	25	18	14	11
S.	B.	5·6	3·3	3·5	5·5	4·2	5·6	5·0
	E.	4·1	5·0	8·3	9·8	7·9	7·8	7·3
	N.	61	61	61	37	16	8	7

[1] The absolute values of the velocities are not inter-comparable because ascents are not made in strong winds in England and the anemometers are of different types and have not been compared.

Increase in Wind Velocity—continued.

B = Berlin, E = England. N = number of observations for England.

Heights	Surface	0·5 km.	1·0 km.	1·5 km.	2·0 km.	2·5 km.	3·0 km.
		Year.					
W. B.	6·9	6·3	7·1	7·1	7·5	8·5	9·2
W. E.	5·9	6·0	7·8	9·1	8·8	9·1	8·7
N. B.	5·3	3·3	4·0	4·6	4·5	5·0	6·4
N. E.	5·7	4·6	5·6	6·1	5·3	6·4	10·4
E. B.	5·4	4·1	4·7	4·6	5·0	5·0	6·3
E. E.	5·9	5·0	5·9	5·3	5·7	5·2	5·1
S. B.	5·9	6·7	6·4	7·3	7·0	8·7	9·0
S. E.	4·4	5·6	8·1	9·1	7·5	6·7	7·1
Mean of Means B.	5·9	5·1	5·6	5·9	6·0	6·8	7·7
Mean of Means E.	5·5	5·3	6·9	7·4	6·8	6·9	7·8
Mean for all winds irrespective of magnitude for Berlin, 1905-6-7	4·9	4·3	4·6	4·3	4·8	5·6	6·4

The velocity therefore increases with the height, but there is little change between 1 and 2 km. The smallest increase is in N. and E. winds, but in summer the increase in E. winds is progressive throughout. The increase in the first 500 m. is always less in summer than in winter, corroborating the results found from the rotation with regard to the effect of convection. The following table gives the results for Berlin deduced from those cases only in which a height of 3 km. was reached, and the wind at 1 km. was 5 m.p.s. and upwards :—

Deviation and Increase in Wind Velocity, Berlin.

Heights	Surface	0·5 km.	1·0 km.	1·5 km	2·0 km.	2·5 km.	3·0 km.
W. 44 cases R.	—	16°	20°	21°	19°	20°	22°
W. 44 cases V.	5·9	5·3	6·9	6·7	7·0	8·2	8·9
N. 14 cases R.	—	18°	23°	25°	24°	25°	25°
N. 14 cases V.	5·6	4·3	4·8	5·3	5·5	5·9	6·8
E. 16 cases R.	—	26°	27°	34°	37°	39°	44°
E. 16 cases V.	5·3	5·4	5·3	5·6	6·1	6·3	6·3
S. 30 cases R.	—	35°	45°	44°	45°	46°	46°
S. 30 cases V.	5·7	6·4	5·3	6·0	6·9	8·2	9·0
Mean of all 104 cases R.	—	24°	29°	30°	30°	31°	33°
Mean of all 104 cases V.	5·7	5·5	5·9	6·1	6·6	7·6	8·3

Thus except for E. winds there is no change in the rotation between 1 and 2 km., and for W. winds there is no change in the velocity in the same layer.

The following table gives the frequency of different rotations for a height of 500 m. at Berlin (Lindenberg) :—

Deviation in degrees	−45°	−34°	−23°	−11°	0	11°	23°	34°	45°	56°	68°	79°	90°	101°	Total
W.	—	—	5	4	35	24	37	10	16	5	2	—	1	—	139
N.	—	—	2	3	15	7	8	—	5	—	2	—	—	—	42
E.	1	—	—	1	11	3	13	4	9	1	2	2	2	—	49
S.	1	—	5	1	4	—	13	8	21	3	6	2	5	1	70

The irregularities probably arise through the tendency of the observers to estimate in even ' points ' when the direction is nearly half-way between two points. The most frequent deviation for E. and W. winds is then 1 point (11°), for N. winds nothing and for S. winds 3 points (34°). In addition to showing the smallest deviation, N. winds show greater regularity than the others, while E. and S. winds show the least.

Berson's results lead to the following values for the total rotation in cyclones and anticyclones :—

Heights	0·5 km.	1·0 km.	1·5 km.	2·0 km.	2·5 km.	3·0 km.	4·0 km.	5·0 km.
Cyclones . .	4°	0°	−2°	−2°	2°	3°	−4°	−7°
Anticyclones .	10	27	33	43	50	57	58	63

The horizontal motion of the balloon would tend to increase the rotation in anticyclones and to diminish it in cyclones, and this probably accounts for the large difference found. Berson concluded that only part of the difference could be accounted for in this way, and that there was a considerable difference after correcting for this effect. The results of kite observations do not agree with this conclusion. The mean rotations, deduced from the Berlin observations in 1905, are as follows :—

Heights	1 km.	2 km.	Number of Cases	
			1 km.	2 km.
Anticyclonic . . .	25°	33°	54	26
Cyclonic	27°	37°	110	52

or including only those cases which reached 2 km. :—

Anticyclonic	30°	33°
Cyclonic	30°	37°

These values agree very nearly with the general mean values found above, *i.e.*, 29°, 32°. Two cases, in which the wind was very weak and completely changed its direction, have been excluded. It may be said therefore that the mean rotation of the wind in the first 2 km. is practically independent of the direction of curvature of the isobars.

The increase in velocity, expressed in terms of the ratio of the observed wind to the mean surface wind, under different pressure conditions, is, according to Berson, as follows in different layers (A anticyclonic, C cyclonic) :—

Heights	0–9·5 km.	–1·0 km.	–1·5 km.	–2·0 km.	–2·5 km.	–3·0 km.	–4·0 km.	–5·0 km.	>5·0 km.
Ratio A . .	1·61	1·67	1·66	1·86	1·96	2·03	2·40	3·15	4·07
	—	—	1·00	1·11	1·17	1·22	1·44	1·89	2·44
Ratio C . .	1·96	2·00	2·09	2·17	2·45	2·49	2·66	3·57	5·03
			1·05	1·09	1·23	1·25	1·33	1·79	2·52

Thus at all heights the ratio is greater in C than in A. The second rows have been introduced to show that the ratio to the wind in the layer 0·5–1·0 km. is practically the same for the two cases, so that the difference arises in the surface layer.

The kite observations for 1905 lead to the following results for the velocity in m.p.s. in the two cases :—

	Velocity			Ratio	
	Surface	1 km.	2 km.	1 km.	2 km.
A (1) .	3·6	7·1	8·4	1·97	—
A (2) .	4·1	8·2	8·4	2·00	2·05
C (1) .	5·6	10·7	10·7	1·91	—
C (2) .	5·9	10·5	10·7	1·78	1·82

The rows (1) include all observations; (2) those only in which the ascent reached 2 km. The surface wind is the mean of the values at the time of observation. The ratio is less in C than in A, but the method of obtaining the surface value is different from that used by Berson, so that it is not quite certain that the results are contradictory. The results seem to imply that the difference is largely accidental and that the real difference is small. It would of course be natural to suppose that the surface friction and irregularities would produce a diminution in velocity which increased at a greater rate than the velocity itself, and this would accord with Berson's results.

Anode Rays and their Spectra. By Dr. Otto Reichenheim.

[Ordered by the General Committee to be printed *in extenso*].

In 1886 Dr. Goldstein found two sorts of positive rays in vacuum tubes, containing a perforated cathode, one passing behind through the cathode—the canal rays—the other going from the cathode in the same direction as the cathode rays, which he called K_1-rays, and which are now known in English literature as ' retrograde rays.'

These rays owe their origin to the high fall of potential near the cathode; and so we may expect that positive rays can arise at any part of the space of discharge if it is possible to produce a sufficiently high fall of potential.

The fall near the anode in a vacuum-tube filled with any indifferent gas, as H_2, N_2, or helium, is usually 20 to 40 volts. As Gehrcke and I found two years ago, this fall can grow suddenly to many thousands of volts if one introduces small quantities of halogen vapour into the tube. From such anodes with high fall we found that positive rays were emitted. These we called anode rays.

Fig. 1 shows an anode-ray tube. K is an ordinary cathode of aluminium; the anode is formed by a stick A of a mixture of a halogen salt and graphite which is surrounded by a glass tube; through this tube passes a copper wire, which conducts the current to the salt, so that the surface of the salt mixture serves as the anode.

If the current passes through the tube the surface of the salt, for instance LiI, gets melted and develops vapour of iodine, which promotes a high fall of potential; the positive lithium ions on the surface of the melted salt get their velocity in this field and appear in the tube as anode rays. These rays show the spectrum of lithium; they produce on the glass the yellow fluorescence characteristic of positive rays; they are emitted at right angles to the surface from which they come; they are deflectable by electric and magnetic fields in the sense of positive charged particles.

Sodium rays are yellow, Ca rays violet, barium and strontium rays blue; about the spectra I will speak later on. If one had a sufficient

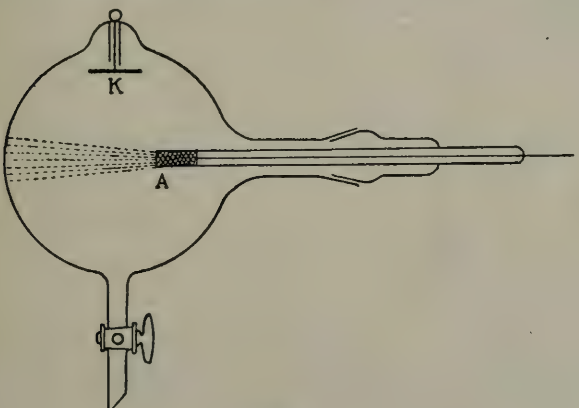


Fig. 1.

quantity of RaI_2 or $RaBr_2$, I think, there would be no difficulty in making Ra rays—that is, rays of positively charged Ra-atoms.

We measured the velocity and the relation between charge and mass of these rays. The following table shows that the velocity of these rays, which depends on the electric field at the anode, is about the same as that of canal rays, and that it appears correct to assume that these rays consist of positively charged atoms:—

—	v cms/sec	$\frac{e}{m}$	m/m_H	Atomic Weight
Sodium . .	$1{\cdot}76 \times 10^7$	$0{\cdot}40 \times 10^3$	23	23
Lithium . .	$2{\cdot}40 \times 10^7$	$1{\cdot}15 \times 10^3$	8·3	7
Strontium . .	$1{\cdot}08 \times 10^7$	$0{\cdot}21 \times 10^3$	90	88

The vapours of halogens can also produce high electric fields at any other point of the discharge, where there is a constriction of the path, and produce positive rays there.

If one fill a tube such as is illustrated in fig. 2 with H_2, evacuate it and pass a current from A_1, the anode, to the cathode K, then cathode rays go out from the cathode, and striction-cathode rays out of the tube 1, 2, at 2, but no positive rays are to be found in the tube. If we now introduce any halogen vapour into the tube, not only does the fall at the anode rise, but a high fall is also created near 1, and hydrogen-anode rays are emitted from A_1 and striction-anode from A_2.

If we have helium instead of H_2 in the tube together with a halogen, helium rays are produced.

Last winter I endeavoured to ascertain the cause of the remarkable power of the halogen vapours to increase the fall at a constriction of the path of discharge; and I found that the following hypothesis is supported by experiments of which time does not allow me to give an account: the halogens are, in accordance with their electro-negative character, much more inclined than other gases to form negative ions,

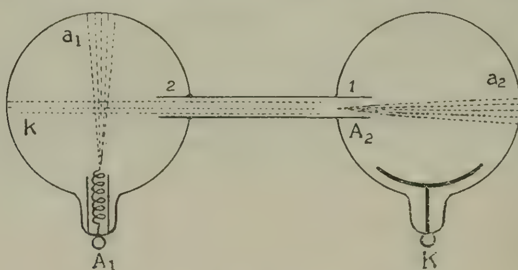


FIG. 2.

or, what is the same, to absorb negative electrons; and where there is a decrease of electrons one always finds an increase in the fall.

If, now, the tendency of the halogens to form negative ions is the explanation of the high fall at the anode, then when a perforated anode is used those negative ions should become accelerated and appear behind the anode as negatively charged atomic rays, in the same manner as positively charged rays (the canal rays) pass through a perforated cathode.

In a tube like the one shown in fig. 3, I tried to find these rays. K is an aluminium cathode; into the big tube leads another glass tube, B. In the end of this tube there is fused the anode *a*, a platinum plate which has a central slit. C is a cylinder of wire gauze, D a metallic diaphragm, C and D are in metallic connection with each other and form a closed conductor inside which there can be no electric field. They can be connected by a wire with the pole of an electric machine. F is a fluorescent screen.

If there is a mixture of H_2 and I_2 vapour in the tube, there is, in a suitable vacuum, an anode fall of about 4,000 volts; from *a* the H_2 anode rays (already mentioned) enter into the big vessel. In the opposite direction, towards F, there pass not only negative electron-

rays (cathode rays), but also atomic rays. If one examines these atomic rays in a magnetic field one finds that they do not carry as expected a negative charge, but a positive charge. As these rays come from the anode and have, against all expectation, just as the K_1 rays, a positive charge, I called them A_1 rays.

Thus we see that positive rays pass through the electrode *a* whether it is acting as cathode or as anode. In the first case these rays are canal rays; in the second case A_1 rays.

Without supposing that here there is some radio-active process going on, we must conclude that these A_1 rays obtain their velocities as negative ions.

If afterwards they show a positive charge they must have dissociated negative electrons on their way. So the hypothesis seems permissible that in gases at low pressures material particles, having a certain velocity, dissociate negative electrons. This hypothesis of the origin

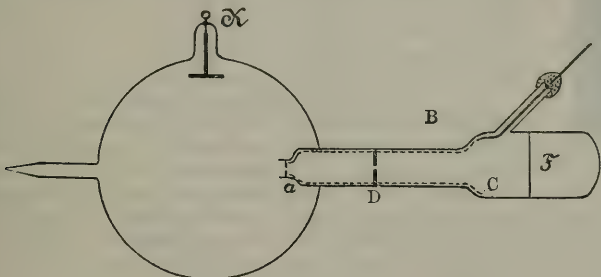


FIG. 3.

of K_1 and A_1 rays is in accordance with the results of Willy Wien, for it will be remembered that he found that a bundle of uncharged canal rays becomes positively charged during their passage.

The following diagram shows all the rays carrying electric charges in a vacuum-tube (fig. 4):—

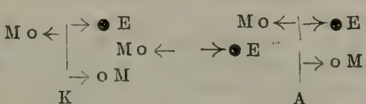


FIG. 4.

A represents a perforated anode.
K ,, ,, cathode.
Black points E represent electrons.
Circles M represent positively charged particles.

The rays leaving the anode seem to be identical with those leaving the cathode, if one supposes that the rays at the anode have their origin at a gas-cathode situated just in front of the surface of the anode.

In regard to the spectra of the anode rays it may be mentioned that the alkali rays show about the same spectrum as in the electric arc, a spectrum which consists of series. The spectrum which the anode rays from the metals of the alkaline earths emit is much simpler than

the one they show in the electric arc. The difference will be seen from the following diagram (fig. 5):—

This shows the spectrum of barium when it is used as metallic anode in a Wehnelt tube, and when the currents sent through the gas are so great that the metal begins to evaporate. Then the light near the anode throws a spectrum which is about the same as the one the metal shows in the electric arc. Below this spectrum is shown that of barium anode rays. It is easily seen that the first spectrum has many more lines than the second one, which is the spectrum of the anode rays.

Fig. 5.

The barium rays show a spectrum of the same type as that of the rays due to other alkaline earths, as they all have *one* line, which has no relation to any other, an isolated line, and then a few pairs of the same difference of vibration-frequency which are connected with the atomic weight in the well-known way detected by Runge and Paschen. So we may suppose that the lines owe their origin to charged atoms.

By studying the spectra of anode-rays it will be possible to decide also for other elements which lines are emitted by isolated atoms and which are due to more complex systems. And as these spectra are very simple we may hope that relations in those spectra will be found for which no such relations have yet been discovered till now: for instance, in the spectrum of iron; but my experiments in this direction are not yet sufficiently advanced to say anything definite about it.

All lines of anode rays which were studied are found to give the Doppler effect; by means of this effect we measured, for instance, the velocity and ratio of e by m of sodium rays, and found a mass equal to that of the sodium atom.

I may mention that, when canal rays are moving towards the observer, one finds two spectrum lines instead of one. One of these has the ordinary wave-length and one is shifted towards the violet; in German called by Stark 'die ruhende Intensität' and 'die bewegte Intensität.'

The explanation of the shifted line is given by the theory of the Doppler effect; but the origin of the 'ruhende Intensität' is problematic, and many and not very satisfactory theories are made about it.

For the solution of the problem of the unshifted line a result may be important which I found in the Doppler effect of the rays from the alkaline earths. The spectrum of Sr-rays shows one isolated line and two pairs. The surface of the anode emits only the isolated line; the other lines only appear in the ray itself. And in observing the Doppler effect one finds that only the isolated line shows both the shifted and unshifted lines; the first being emitted by the ray, the second by the surface of the anode. The pairs only show the shifted lines, and not the unshifted.

In the case of canal rays there are always the same lines emitted by the ray and the surrounding gas, so it seems to be quite natural to find both the shifted and unshifted lines.

Here, in the case of anode-rays, the ray emits lines different from those of the gas, and so one finds, as to be expected, only the shifted lines.

On Threefold Emission-Spectra of Solid Aromatic Compounds.

By Professor E. GOLDSTEIN.

[Ordered by the General Committee to be printed *in extenso*.]

SOME years ago I observed [1] that bright, fluorescent, and phosphorescent light is emitted by a number of aromatic solid compounds—for example, naphthalene, xanthone, anthracene, &c.—if cathode-rays strike on these substances, cooled by liquid air for preventing their evaporation and decomposition. In this way I was also able to obtain bright-light emission from a great many substances, which at an ordinary temperature are liquid bodies—for example, benzene, the three xylenes, benzonitrile, the chinolines, acetophenone, &c. The light emitted by these substances gave bright *discontinuous* spectra of a great variety, all consisting of bands of various width and intensity.

Since that time I have extended this research on nearly all aromatic substances which I could obtain in any way, and have thus obtained about two thousand emission-spectra of aromatic substances and of mixtures of such substances with other bodies.

Of course, time does not allow me to give a complete report of this work. Here I just want to speak about *one* result of my experiments.

In the beginning I was satisfied to observe just a single spectrum for each substance, because it was thought that every substance could emit only one single spectrum. But soon I found that the complexity of phenomena is much greater than it seemed at first sight. For each substance does not show only *one* spectrum, but, according to the conditions of the experiment, there appear *three* spectra, which are quite different from each other and have no coincident maximum. I call these three kinds of spectra respectively the *initial-spectrum*, the *chief-spectrum*, and the *solution-spectrum* of the substance.

At the first moment, when cathode-rays fall upon the substances, there appears quite alone and bright the spectrum which I call the *initial-spectrum*. Then the brightness of the initial-spectrum diminishes and gets fainter and fainter till its intensity becomes very small, but it never *entirely* disappears. When the initial-spectrum gets fainter, the *chief-spectrum* at the same time appears and grows brighter and brighter. The chief-spectrum is for a great number of substances so characteristic that it is possible to recognise the substance in this way at a glance and without measuring the wave-lengths, just as you can recognise nitrogen by its well-known bands, or hydrogen, mercury, and helium by their line-spectra. This is even the case with isomeric substances, for one is able to distinguish at a glance, for instance, the three isometric xylenes or other isometric aromatic hydro-carbons. The third kind of spectra, which is quite different from the two others, appears if an aromatic substance is dissolved in any other liquid or melted compound and the solidified solution is exposed to cathode-rays.

Now let me just say a few words on the properties of each of the three kinds of spectra.

The *chief-spectra* always begin from the infra-red, never reach the violet end of the visible spectrum, but end about the middle part of

[1] *Verhandl. d. Deutsch. Physik. Ges.*, vi. 156 and vi. 185 (1904).

it in the green or in the blue, sometimes even in the yellow. I never observed that a chief-spectrum passes the wave-length of λ 460. The chief-spectra consist of narrow-channelled bands, which nearly always have their sharper boundary toward the violet end of the spectrum. The number of the bands varies within a wide range for the different substances between a few strips and several dozen. The distances between them appear generally irregular. The substances, when they send out their chief-spectrum, look red or yellow or green, or of any other tint which occurs with fluorescent minerals or inorganic salts. On the other hand, the light which is emitted during the first moments of radiation and belongs to the initial-spectrum is—at least, for colourless substances—always *blue*. The discontinuous *initial-spectra* of two substances are, like their chief-spectra, never quite the same, but as in their general appearance they are rather similar to each other, at least in the visible part of the spectrum, so one cannot recognise a substance at a glance by its initial-spectrum as one can by the chief-spectrum, but measures of its wave-lengths are necessary. The initial-spectra begin always like the chief-spectra in the red, but not only reach into the green or blue, but go on into the ultra-violet. One type of initial spectra occurring especially frequently invariably consists of *six* groups of bands. Each of the six groups is formed by the same number of strips at the same relative distance and intensity; and as the relative distance of the groups themselves is also not very different—at least in the prismatic spectrum—the whole spectrum gives the impression of having a *very high regularity*. Such spectra, consisting of six groups, with different wave-lengths for each individual substance, are, for example, the initial-spectra of mesitylenic acid, of metatoluic acid, of the anhydride of benzoic acid, of toluene and of its halogen substituted derivates—and of many other substances, especially of those aromatic bodies whose molecules contain a single-ring group.

In the groups which contain two or even more benzene rings, and especially in condensed substances, one finds also other types of initial-spectra, all extending from red into the ultra-violet, which I will not speak of in this short report.

The *third* spectrum of aromatic compounds is shown in very characteristic forms especially by dissolved compounds of the condensed type; for instance, by naphthalene and most of its derivates. The chief spectrum of naphthalene shows the wave-lengths

539 (very bright)	589 (very bright)
555	615 (probably a doublet)
560	630
573	648

λ 539 and 589 mark sharp boundaries on the violet side, the other wave-lengths belong to the middle of narrow strips.

The spectrum of the same naphthalene, if dissolved in monochlorobenzene (which itself gives only a faint and almost continuous spectrum) shows the following wave-lengths (all for the middle of the narrow strips):—

473, 483 } bright	505, 510 } rather bright	517, 523 } rather faint	540, 545 }	557, 565 } rather faint

582 faint.

Beyond this last strip the illuminated ground cannot be separated distinctly into strips.

One cannot, however, speak of a *single* solution-spectrum of a body, as the solution-spectrum of the same substance varies greatly with the solvent.

The solution-spectrum of naphthalene, for example, shows differences, if the naphthalene has been dissolved in metaxylene or in orthoxylene or in paraxylene. Therefore, if one substance shows remarkable differences in *isomeric* solvents, one cannot wonder that the solution-spectra of the same substance show even much greater differences if more different solvents are used; for instance, if we compare the solution-spectra of the same substance when dissolved either in a xylene or in aniline, pyridine, ethyl-alcohol, and ethyl-ether.

On the other hand, each condensed compound and its derivates, *even in the case of isomers*, show an individual solution-spectrum. The chief spectrum of the β-bromonaphthalene presents a similar aspect to the chief spectrum of the α-bromonaphthalene. But the solution-spectra of the two substances, for example, in monochlorobenzene, are *very* different. The solution-spectrum of the α-substance is of a similar type to the solution-spectrum of naphthalene itself, presenting only an appearance of a certain regularity by the occurrence of some doublets, while the solution-spectrum of the β-form is of a quite different type, and shows a most regular structure. It consists of four bands, of quite equal aspect, extending from the red into the blue. Each of the four bands is formed by five narrow strips, the relative distance and intensity of which is quite corresponding in all bands.

The light of the *chief-spectra* is *fluorescent*, and disappears at the moment when the cathode-rays stop.

The light of the solution-spectra is *phosphorescent*, and very often one can see it for some minutes after the discharge which produces the cathode-rays is interrupted.

Only *very small quantities* of a substance are necessary to produce a solution-spectrum bright enough to be remarked and to be measured. For example, one can detect in this way less than the hundred thousandth part of naphthalene dissolved in monochlorobenzene or in methylbenzoic ester.

Of course these phosphorescent solution-spectra are, on the other hand, a very sensitive test for the purity of aromatic substances, or, what is the same, a very sensitive means of detecting very small quantities of admixed foreign aromatic substances. And I am sorry to say that, among many hundreds of preparations of the best obtainable 'purity,' the specimens which did not show very marked signs of impurities could be counted on the fingers of one hand, if there were any at all.

I spent much time and money in getting even very small quantities of certain substances really pure; for example, diphenyle, indene, carbazole, fluorene, and other condensed compounds, and some of the most famous chemists helped me kindly by the best known methods; but at last I had to give up the hope of getting any of these substances in pure condition. Until now they have never been produced in a really pure state, and I fear that the same holds true for all other aromatic bodies.

Some Properties of Light of very Short Wave Lengths.

By Professor THEODORE LYMAN.

[Ordered by the General Committee to be printed *in extenso.*]

THE most refrangible region of the spectrum discovered by Schumann[1] is interesting from two points of view. On the one hand, it affords a new field for the investigation of pure spectroscopy, and, on the other, it offers opportunities for the extension of the study of photo-chemical and photo-electric phenomena.

In the realm of spectrum analysis something has already been accomplished. Absorption and emission of light by hydrogen, oxygen, nitrogen, carbon monoxide, carbon dioxide, argon, and helium have been investigated and the absorption of a considerable number of solids has been studied.

The absorption of gases is perhaps the most striking phenomenon to be found in this region. One millimetre of air at atmospheric pressure is quite sufficient to absorb most of the light of shorter wave length than 1700 Ångström units. The oxygen of the air is the chief agent in producing the effect, for this gas possesses a strong absorption band extending from near λ 1800 to the neighbourhood of λ 1300. The discovery of the more refrangible limit of this band is one of the recent results in this subject.[2]

Hydrogen, argon, and helium when examined in short columns all prove perfectly transparent, while the absorption produced by nitrogen is extremely slight. Carbon monoxide and carbon dioxide, however, each possess absorption spectra characterised by narrow bands.

The behaviour of oxygen is obviously different from that of other simple gases. This difference may be attributed to a photo-chemical reaction typical of this gas.

From the point of view of the emission of light, hydrogen is the most important of the gases examined.[3] It possesses a strong spectrum, very rich in lines extending from λ 1650 to λ 1030. This spectrum is much weakened when capacity is introduced in the discharge circuit; it seems to correspond to the 'secondary' or 'many line' spectrum of hydrogen in the less refrangible region, but it is not continuous with it. Lines of the 'primary' or Balmer type do not appear to exist in the region between λ 2000 and λ 1250. This is to be expected from theoretical considerations, for the chief series as given by Rydberg[4] lies on the less refrangible side of λ 2000, and the chief series as given by Ritz[5] lies on the more refrangible side of λ 1250. It seems probable that the first line of the series predicted by Ritz does exist, but so far experimental difficulties have prevented its identification.

Next in importance is the spectrum produced by carbon monoxide; exactly the same spectrum is given by carbon dioxide. It consists of a large number of bands, whose heads point toward the violet and whose

[1] *Smithsonian Contributions to Knowledge*, No. 1413.
[2] *Astrophysical Journal*, vol. xxvii. No. 2.
[3] *Ibid.*, vol. xxiii. No. 3.
[4] *Ibid.*, vol. vi. p. 233.
[5] *Ann. d. Physik*, v. 25, 1908, p. 667.

tails stretch toward the red. This spectrum resembles the fourth group of Deslandres,[1] and appears to form a continuation of it. The bands extend from the region λ 2600 to λ 1300; they afford a wide field for a test of Deslandres' law.

The spectrum of argon consists of a considerable number of characteristic lines extending from λ 2000 to the limit of the spectrum.

Up to the present time it has been impossible to attribute any lines to helium, to oxygen, or to nitrogen, in that part of the spectrum more refrangible than λ 1850.

A great number of solids have been examined, with the hope of finding some substance more transparent than white fluorite.[2] The results have been negative. Rock salt in thicknesses of one or two millimetres begins to absorb strongly in the neighbourhood of λ 1750. B_2O_3 is even less transparent.[3] Quartz in thickness of 2 mm. absorbs strongly at λ 1500, and the absorption increases rapidly with thickness; even white fluorite becomes opaque near λ 1250. It was the opacity of fluorite which set the limit to Schumann's progress in the extreme ultra-violet. It was by the removal of all fluorite from the light path and by the use of a grating, that the writer has been able to extend the spectrum to its present limit—λ 1030.

It is interesting to note that the positions of the absorption bands demanded by Maclaurin's [4] dispersion formula for rock salt and fluorite lie in the neighbourhood of λ 1265 and λ 846 respectively; while on the experimental side strong absorption appears to begin near λ 1750 for rock salt and near λ 1250 for fluorite.

The investigation of the spark or arc spectra of solids has met with very little success. Apart from a few lines in aluminium extending into the neighbourhood of λ 1650 almost nothing has been accomplished.[5] The difficulties are obvious. It is necessary to produce a spark or arc in such a manner that the light characteristic of the substance in question may enter the vacuum spectroscope without suffering absorption. The high potential arc [6] has been tried in this connection, but without result.

On the photo-chemical side of the subject the well-known action of light in producing ozone is perhaps the most conspicuous phenomenon. The fact of importance to be deduced from a study of the Schumann region relates to the rapid increase of this effect with decrease in wave length. The very wave lengths which are most strongly absorbed by the air are those which are most active in the production of ozone.[7] It seems probable, therefore, that the strong absorption of oxygen is connected intimately with this photo-chemical action.

The formation of ozone may play a considerable part in determining the relative velocity of the ions produced by ultra-violet light.

In photo-electric phenomena it is well known that for many substances the discharge of negative electricity becomes more pronounced as the wave length of the exciting light is decreased. In the Schumann region this effect becomes very striking, as the following experiment will serve to indicate.

[1] *Compt. rend.*, V. cvi., 1888, p. 845.
[2] *Astrophysical Journal*, vol. xxv., No. 1.
[3] *Ibid.*, vol. xxviii. No. 1.
[4] *Proc. Roy. Soc.*, A, vol. 81, p. 367.
[5] Kayser, *Handbuch*, vol. iii. p. 339.
[6] *Physical Review*, vol. v. p. 1.
[7] *Astrophysical Journal*, vol. xxvii. No. 2, p. 98.

A discharge tube of the type usually employed by the writer is closed by a fluorite window, and upon this window is mounted an air-tight 'screen chamber' 1 cm. thick, also closed by a fluorite window, which communicates with an air-pump. Above the 'screen chamber' is the air-tight condenser chamber, which may also be exhausted. This last chamber contains a clean zinc plate, 9 mm. in diameter, and below it a brass guard ring. The apparatus is so constructed that the light from the discharge tube, after passing through the screen chamber, falls directly on the zinc plate; the brass ring is protected from illumination and is earthed. The zinc plate is connected to a gold-leaf electrometer of the simplest type, and is given a negative charge. The discharge tube is filled with a mixture of hydrogen and carbon monoxide, at about 2 mm. pressure, and the condenser chamber is exhausted. Now, if the screen chamber is filled with air at 1 atmosphere pressure, on starting the discharge tube the leaves of the electroscope collapse slowly. On the other hand, if the screen chamber is exhausted to about 1 mm. pressure, on starting the discharge tube the leaves of the electroscope collapse almost instantly. The phenomenon is so striking that the simplest electric arrangements serve to show it.

It is known from spectroscopic measurements that the spectrum of a mixture of hydrogen and carbon monoxide consists of a great number of lines and bands extending from the region of the visible to the limit of the spectrum as set by fluorite— λ 1250. It is also known that a layer of air, at atmospheric pressure, 1 cm. thick, absorbs all wave lengths shorter than λ 1750 very strongly, and that a layer of air at 1 mm. pressure, 1 cm. thick, shows little absorption until the region of λ 1300 is reached. Thus when the "screen cell" is filled with air, light from the red end of the spectrum—near λ 6800 to λ 1750—falls upon the zinc plate; when the cell is exhausted light from the visible to λ 1300 falls on the plate. The addition of the region between λ 1750 and λ 1300 increases the leak by at least tenfold. Thus it seems probable that the photo-electric effect for zinc increases rapidly with decrease in wave length as the limit of the Schumann region is passed. It is the rapidity of this increase which is the striking point.

In the volume ionisation of gases the same state of things holds true. Lenard investigated the phenomenon, and lately Professor Sir J. J. Thomson has proved its reality. The amounts of ionisation obtained were, relatively speaking, small. It appears, however, that if care is taken to employ light of the shortest wave length, the ionisation obtained is quite considerable.[1] Here again the rapidity of the increase of the effect as the Schumann region is entered is the important point.

This phenomenon of volume ionisation in its relation to short wave lengths has some bearing on the behaviour of vacuum tubes, and accounts for a part of the effects usually attributed to 'Entladung strahlen.'[2]

Such, in brief, are the results which have been obtained in this small but interesting spectral region. A complete description of the apparatus which has been used and the methods which have been employed is to be found in the articles to which references have been made.

[1] *Astrophysical Journal*, vol. xxviii. No. 1, p. 56; *Nature*, April 23, 1908, p. 582.
[2] *Astrophysical Journal*, vol. xxviii. No. 1.

Dynamic Isomerism.—Report of the Committee, consisting of Professor H. E. ARMSTRONG (*Chairman*), Dr. T. M. LOWRY (*Secretary*), Professor SYDNEY YOUNG, Dr. C. H. DESCH, Dr. J. J. DOBBIE, Dr. M. O. FORSTER, and Dr. A. LAPWORTH. (*Drawn up by the Secretary.*)

Dynamic Isomerism in relation to Luminous Phenomena.[1]

A. *Absorption Spectra.*

DURING the past year two series of investigations on 'The Relationship between Absorption Spectra and Isomeric Change' have been completed and published.[2] Attention may now be directed to the decisive evidence adduced in these communications that the presence or absence of a band in the absorption spectrum of a camphor-derivative is in no way dependent on the occurrence or non-occurrence of isomeric change.

(1) *Nitrocamphor*, which changes rapidly in neutral alcoholic solutions, does not give rise to an absorption band [3] even when the isomeric change is stimulated by the addition of an acid. Very strong bands are observed in the spectra of solutions of salts of nitrocamphor; yet these salts are not known to exist in more than one form.

(2) *α-Chlorocamphor*, on the other hand, which changes only in the presence of an alkali, exhibits a strong band in neutral and in alkaline solutions indifferently, the band being only slightly intensified by the addition of an alkali.

(3) The *β-sulphonates* derived from α-chlorocamphor also undergo isomeric change only when an excess of alkali is added; but this has the effect of weakening instead of intensifying, the absorption bands which are produced by neutral solutions of these salts.

(4) In the case of the isomeric α- and β-bromo-derivatives of α methyl-camphor, it is found that the methyl-camphor band is not apparent in the β-compound $C_8H_{13}Br\left\langle\begin{array}{l}CH.CH_3\\ |\\ CO\end{array}\right.$, but is in the α-compound $C_8H_{14}\left\langle\begin{array}{l}C\,Br.CH_3\\ |\\ CO\end{array}\right.$, in spite of the fact that the former contains a displaceable α-hydrogen atom, and that no such atom is present in the latter, which therefore is unable under any condition to undergo keto-enolic isomeric change.

The decisive experiments that have been made with these optically-active substances have an important bearing on the general theory of the

[1] The general discussion which follows is an amplification in the light of more recent evidence of considerations which were advanced by Armstrong in 1902 and by Armstrong and Lowry in 1903 (*Proc. R.S.*, **72**, 258–264) in a paper bearing these words as its sub-title.

[2] *Trans. Chem. Soc.*, 1909, **95**, 807–823; 1340–1346.

[3] The 'shallow band' referred to in the previous report was found to be merely a 'step-out,' the effect of which had been exaggerated by under-exposure.

origin of colour in carbon-compounds. Broadly speaking, two alternative conceptions have been advocated. On the one hand, it has been suggested that the selective absorption of light by coloured compounds is due to a peculiar structure of the molecule and that certain types of structure in which ethenoid linkages and other unsaturated centres are present are specially susceptible to the 'optical resonance' which is universally recognised as the cause of the absorption of light by vapours and is probably also the cause of the less abrupt absorption of light by liquids and solids. On the other hand, it has been suggested that colour is due not so much to molecular structure as to change of structure, and that only those molecules which are capable of existing in isomeric forms, and may, therefore, be supposed to be in a state of continued oscillatory isomeric change, are capable of resonating to light of definite periodicity. This theory was introduced by Hewitt [1] to account for fluorescence; it was applied by Armstrong and Lowry [2] in explanation of the storage of energy in phosphorescent and in triboluminescent substances, and has been put forward by Baly and Desch [3] and by Baly and Stewart [4] as an explanation of colour in organic compounds; it has also been used by Baeyer [5] and by Green [6] to account for the specially intense colour of some of the derivatives of triphenylmethane.

Two different types of isomeric change have been specially considered, namely—

(1) Isomeric changes involving the oscillatory transference of an atom of hydrogen from carbon to oxygen as in ethylic acetoacetate, from nitrogen to oxygen as in isatin, and from oxygen to oxygen as in *p*-nitrosophenol.

(2) Changes involving only a rearrangement of the bonds in the molecule without any substantial alteration in the relative positions of the atoms, as, for instance, in Kekulé's well-known hypothesis, in which an oscillation of the linkages in benzene was assumed to take place in order to account for the identity of the 1 : 2 and 1 : 6 diderivatives.

Changes of the former kind have been carefully investigated in several typical compounds and have been found (in direct contradiction to Laar's hypothesis of tautomerism) to be subject to the ordinary laws governing chemical change. The occurrence of change of the latter type is at present purely speculative, as no case is known in which the occurrence of such a change has been demonstrated; but, in view of the extreme stability of the linkages in compounds such as the sugars, it is exceedingly probable that if ever an example of the second type of change be discovered, it will be found to obey the same laws, and to be governed by the same conditions as those which obtain in isomeric changes of the first type.

The most important consequences of the application to luminous phenomena of considerations based upon the ordinary laws of chemical change are perhaps those concerning the effects produced by the presence of foreign substances, and by the change from the fluid to the solid state.

[1] *Proc. Chem. Soc.*, 1900, **16**, 3; *Zeit. phys. Chem.*, 1900, **34**, 1.
[2] *Proc. Roy. Soc.*, 1903, **72**, 258–264.
[3] *Trans. Chem. Soc.*, 1904, **85**, 1029; 1905. **87**, 766.
[4] *Ibid.*, 1906, **89**, 502. [5] *Annalen*, 1907, **354**, 152.
[6] *Proc. Chem. Soc.*, 1908, **24**, 206.

B. *Catalytic Action of Impurities.*

It cannot be insisted too strongly that no actual case of 'intramolecular change' is known to chemistry. The part which a chain or circuit of molecules plays in bringing about chemical action is now very generally recognised; it is unnecessary to do more than mention, as instances, the part played by moisture in determining the combustibility of gases, the importance of impurities in conditioning the dissolution of metals by acids and the need of a catalyst to bring about the isomeric change of phenylchlorimide; it is, however, permissible to emphasise the fact that neither the dissociation of a molecule of ammonium chloride nor the transference of a hydrogen atom from carbon to oxygen in a molecule of nitrocamphor—changes which, if such a thing were possible, might be expected to provide excellent examples of single-molecule transformations—can be effected without the aid of a foreign substance, and the establishment of a complex heterogeneous molecular circuit. It is therefore legitimate, in considering the connection between luminous phenomena and chemical change, to apply as a critical test to any particular relationship that may be proposed the question as to whether the action can or cannot be arrested by the elimination of impurities. If the phenomenon can be proved to be manifest only in presence of a catalyst, not when pure materials are used, there is good evidence that it may be dependent on chemical change; if the effect can be proved to be independent of impurities, it must be regarded as inherent in the physical nature of the material. Positive evidence that the presence of a catalyst is essential has been forthcoming in the case of the phenomena of mutarotation and in the case of phosphorescence, as both manifestations may be arrested by suitable methods of purification; these may, therefore, be correctly attributed to chemical rather than to purely physical changes. Refraction, dispersion, and optical rotatory power, on the other hand, are properties which do not appear to be dependent in any way on the presence of foreign substances and must therefore be referred to physical and not to chemical characteristics of the molecule. In an intermediate group may be placed (1) colour, (2) fluorescence, and (3) triboluminescence; it is in reference to these three phenomena that controversy and discussion have for the most part been carried on.

Of the three phenomena quoted, that of *triboluminescence* is the one in which the clearest evidence is available, crystals of saccharin, for instance, showing the phenomenon very irregularly, highly purified crystals giving no 'flash' whatever[1]; there is, therefore, good reason to adhere to the view put forward in 1903 that the flash of light which appears when the crystal is crushed is due to the sudden liberation of chemical energy stored in the crystal, for instance by the separation of a certain quantity of a labile form during rapid crystallisation. The case of *fluorescence* is less clear, as no investigation of a critical character on the influence of impurities in determining fluorescence appears to have been carried out. It is therefore impossible at present to do more than to point out that fluorescence is often manifest only under special chemical conditions, *e.g.*, in presence of an alkali, or

[1] See Armstrong and Lowry, *loc. cit.*, p. 261.

after dissolution in concentrated sulphuric acid [1]; these conditions are often precisely those which determine the occurrence of oscillatory isomeric change: it is therefore permissible to adhere provisionally to the theory that fluorescence is dependent on change of structure until definite evidence to the contrary is forthcoming.

The phenomenon of *colour* is on an altogether different footing, since exhaustive experiments have frequently been made in the hope of removing colour by careful purification of the material. These experiments have led to results of two types: in the case of some compounds, such as picric acid and *p*-nitrophenol, the colour of the crude material has actually been removed by purification or by crystallising out under special conditions; in the case of other compounds, such as quinone and *o*-nitrophenol, no indication whatever has been obtained which would even suggest the possibility of bleaching the compound. It is therefore impossible to resist the conclusion that colour, in the case of the latter group of substances, is an essentially physical phenomenon of the same general type as the closely related phenomenon of refraction and that it does not depend on any fluctuation of structure to which the ordinary laws of chemical change can be applied. The case of substances which can be rendered colourless by suitable methods of purification requires further consideration: it might be suggested that an impurity is able to develop colour throughout the material in much the same way as that in which the phosphorescence of calcium sulphide is developed by the combined action of a trace of bismuth and a trace of a sodium salt,[2] but the view that has been universally adopted is that the mass of the material is merely stained by a trace of some highly coloured dye-stuff and is itself essentially colourless; it is indeed frequently an easy matter for an experienced eye to detect the staining-process by the feeble and variable development of colour which it produces, as contrasted with the intense and uniform colour of materials which are in themselves absorptive. If this view be adopted, it is clear that in these cases also the colour is due, not to change of structure in the original material, but to some characteristic absorptive-power inherent in the (fixed) structure of the staining material.

Note in reference to 'stained materials.'—In considering the properties of stained materials it is important to distinguish three cases. Sometimes the stain is produced exclusively during the preparation of the substance, and may be permanently removed by distillation, by contact with animal charcoal or by similar straightforward methods. There are, however, many substances which cannot be purified in this easy way, since they undergo change continually in contact with the air and give rise persistently to coloured oxidation-products (*e.g.*, indigo-blue from indigo-white); in such instances purification can only be effected under special conditions, and a material partly bleached by purification may easily revert to its original colour if the essential precautions are in any way relaxed. The third case, in which the substance undergoes reversible chemical change, is more puzzling than either of the others, and may easily give rise to erroneous conclusions. Fortunately, the conditions governing such cases are now well under-

[1] Hewitt and Tervet, 'Oxonium Salts of Fluorane,' *Trans. Chem. Soc.*, 1902, **81**, 664.

[2] De Visser, *Rec. Trav. Chim.*, 1901, **20**, 435; 1903, **22**, 133.

stood, as may be shown by referring to some of the examples that have been most fully investigated. It is, for instance, generally recognised that *reversible isomeric change* may occur in such a way as to involve the interconversion of a coloured and a colourless isomeride.[1] Usually both will be present in solution but, on crystallising out, one form only will separate in an approximately pure condition; in some instances, however, the two forms are capable of crystallising with such equal readiness that it is possible to separate out the coloured or the colourless form at will by varying the solvent [2] or the temperature of crystallisation [3]; even when this cannot be done it is often found that rapid crystallisation causes the separation of a mixture of the two isomerides. It is then only necessary to assume that the two forms of the substance are endowed with the property of forming isomorphous mixtures or solid solutions, in order to realise the conditions for the production of stained crystals of absolutely constant colour-intensity, since it will follow (in accordance with a general law) that the constancy of the equilibrium-proportions in the liquid state will be reproduced in the crystals, although the actual ratio of the two components need not be the same in the two phases. *Reversible polymeric changes* involving the inter-conversion of coloured and colourless compounds are familiar in the cases of nitrogen peroxide and the colourless (bimolecular) and blue (unimolecular) forms of *ter*-nitrosobutane [4]; here again it would probably only be necessary for the two forms to be isomorphous, in order to give rise to stained crystals of uniform composition and constant intensity of colour.[5]

The importance of these examples consists in the fact that they provide for the production of stained crystals from which the colour could only be removed by the discovery of methods even more refined than those which are required on the one hand to arrest isomeric change in solution and on the other to effect the separation of isomorphous mixture.

C. *Crystallisation in Relation to Luminous Phenomena.*

Since chemical change is usually checked, if not actually arrested, on passing from the gaseous or liquid to the solid state, it is clear that this should exert a most important influence on any luminous properties which depend for their development on the chemical rather than on the physical activity of the molecule. This is clearly seen in the case of triboluminescence, phosphorescence, and fluorescence, whilst colour may be quoted as an illustration of an optical phenomenon which is not affected in any marked degree by change of state.

[1] This point is in itself sufficient to dispose of the idea that the development of colour is due to oscillatory isomeric change, since if this were the case the separate isomers must necessarily be colourless and only the mixture coloured.

[2] *E.g.*, isonitrosomalonanilide, Whiteley, *Trans.*, 1903, **83**, 34.

[3] *E.g.*, *p*-methoxyphenylphthalimide, Piutti and Abati, *Ber.*, 1903, **36**, 1000.

[4] Bamberger and Seligman, *Ber.*, 1903, **36**, 689.

[5] Equilibrium between colourless and coloured forms has also been postulated as attending certain cases of *ionisation* (*e.g.*, violuric acid has been supposed to acquire its characteristic colour only on passing into the ionised state), but the development of colour is usually due to a change of structure of the kind that has already been considered and in any case the extension of the theory of ionisation to the staining of a colourless crystalline compound by its own ions would be too bold a conception to merit serious consideration.

Phosphorescence.—The storage of energy by phosphorescent bodies is apparently confined to the solid state, though in this category it is necessary to include both vitreous and crystalline solids. Its gradual liberation finds a close analogy in the slow discharge of the residual current from a Leyden jar, and both processes may be regarded as depending on the retarded electrolysis of a viscous medium. It is noteworthy that a great number of compounds which are not phosphorescent at ordinary temperatures become so at the temperature of liquid air,[1] and that conversely the after-glow of many substances which are phosphorescent when cold, disappears when they are heated.[2] In other cases the energy stored up in the crystal is liberated in the form of light only on warming (thermophosphorescence) or on crushing the crystal (triboluminescence or tribophosphorescence). In all these cases the limitation of the phenomenon to the solid state and the profound influence exerted by temperature changes are fully in accord with the view that the energy is stored by means of reversible chemical change, being released only when the rigidity of the material is sufficiently relaxed to permit of electrolysis and chemical change.[3]

Fluorescence, like phosphorescence, is profoundly influenced by the state of aggregation of the material. It is of frequent occurrence in liquids, including solutions in concentrated sulphuric acid, dilute alkalis, water and organic solvents; it is very rare indeed amongst solids. Indeed, in spite of the existence of a few well-known exceptions (anthracene, uranium salts, etc.), it is probable that out of a total of some two thousand fluorescent substances, less than one per cent. are fluorescent in the solid state. There is therefore ample support to be found for the view that fluorescence is due to oscillatory chemical changes of the same general character as those which take place in solutions of nitrosobutane or nitrocamphor, since these are usually (but perhaps not invariably) arrested on passing from the liquid to the solid state. This view is also strongly supported by the close relationship which has been proved to exist between fluorescence and phosphorescence. Thus Wiedemann has shown[4] that eosin, fluorescein, aesculin, quinine sulphate, etc., show a weak after-glow when the solutions are rendered plastic by gelatine and a little glycerine, that they become definitely phosphorescent when the solution is 'set' with gelatine, and that a still stronger phosphorescence is developed when glue is used. Observations of this kind indicate clearly that phosphorescence is essentially identical with fluorescence and differs from it only in the fact that the energy absorbed during insolation is liberated gradually instead of instantaneously: it is therefore legitimate to argue that the strong evidence, obtained independently, that these two phenomena are due to reversible chemical change, becomes doubly strong when they are proved to be merely two varieties of the same type of activity. It may also be pointed out that recent attempts to correlate fluorescence with colour, by introducing the ideas of 'fluorophor' and 'fluorogen' groups (compare 'chromophor' and 'chromogen') do not rest on any direct experimental basis (a sub-

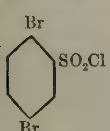
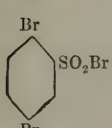
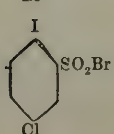
[1] Dewar, *Chem. News*, 1894, **70**, 252–253.
[2] Wiedemann and Schmidt, *Wied. Ann.*, 1895, **56**, 201–254.
[3] The relaxation of molecular forces during crushing is well illustrated by Beilby's work on the flow of metals during polishing and under the influence of mechanical forces generally.
[4] *Wied. Ann.*, 1888, **34**, 446–463.

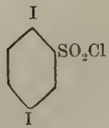
stance may retain its colour and lose its fluorescence by crystallising out from solution), but on a mere analogy, the value of which is highly problematical.

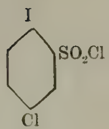
Colour.—In contrast to these cases it is noteworthy that colour is not as a rule affected in any marked way by crystallisation. Certainly the passage from the liquid to the solid state is accompanied by nothing at all analogous to the abrupt bleaching which would almost inevitably take place if colour were really due to any concrete form of oscillatory chemical change, and which forms the most commonplace of observations when dealing with fluorescent colour. It is indeed true that colour is often intensified at high temperatures and reduced by cooling, but these alterations proceed continuously; in this respect they are in direct contrast to the abrupt arrest of chemical change which takes place when nitrogen peroxide is frozen or when nitrocamphor is crystallised out from solution; there is therefore nothing here to justify the contention that colour is due to chemical change rather than to oscillations or vibrations of a 'physical' character not involving any real alteration of structure. On the contrary, the effects of crystallisation are such as to confirm the conclusions arrived at from general considerations and from the effects produced by impurities that colour, unlike phosphorescence and fluorescence, is a physical phenomenon in which chemical change plays no essential part.

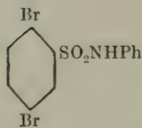
The Study of Isomorphous Sulphonic Derivatives of Benzene.—Report of the Committee, consisting of Principal MIERS *(Chairman) and* Professors H. E. ARMSTRONG *(Secretary),* W. J. POPE, *and* W. P. WYNNE.

IN continuance of previous work a number of members of several series of sulphonic derivatives of para-dihalogen derivatives of benzene have been prepared and crystallographically examined. The substances for which data are given below crystallise in the monosymmetric system:—

		$a : b : c$	Melting point
1.		$2{\cdot}4760 : 1 : 1{\cdot}1439$, $\beta = 95^\circ\ 26'$	71°.
2		$2{\cdot}4792 : 1 : 1{\cdot}1448$, $\beta = 96^\circ\ 49'$	114°.
3.		$2{\cdot}4689 : 1 : 1{\cdot}1537$, $\beta = 95^\circ\ 50'$	102°.

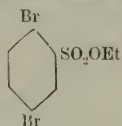
4.  $0 \cdot 8552 : 1 : 0 \cdot 6576$, $\beta = 95° 22'$ . . . . 132°.

5.  $0 \cdot 7288 : 1 : 0 \cdot 6544$, $\beta = 99° 42'$ . . . . 69°.

6.  $0 \cdot 9576 : 1 : 0 \cdot 8364$, $\beta = 99° 30'$ (labile form) . . . 143°.

The following compound crystallises in the orthorhombic system:—

Melting point.

7.  $0 \cdot 8904 : 1 : 0 \cdot 8357$ . . . . . . 106°.

The substances numbered 1, 2, and 3 form a well-defined isomorphous series as is immediately indicated by the close approximation of the axial ratios quoted. The compounds 4 and 5 differ entirely in crystalline character from the foregoing but the similarity of the ratio c/b in the two cases suggests an intimate morphotropic relation as existing between their crystalline structures.

In a series of papers Barlow and Pope have pointed out that the whole space occupied by a crystalline substance can be conveniently regarded as parcelled out amongst the various atoms composing the material and have shown that this mode of treatment leads to the conclusion that the volumes thus allocated to atoms of different elements are, in any one substance, approximately proportional to their valencies. A crystalline substance is thus to be regarded as a close-packed assemblage of spheres of atomic influence in which each of the latter has a volume directly proportional to the fundamental valency of the atom which it contains. The close-packed assemblages referred to are geometrically partitionable into units representing individual molecular aggregates; these should represent in composition, constitution and configuration, the chemical molecules of the substances concerned.

From the study of the crystalline forms of benzene and its derivatives Barlow and Pope have deduced a form of assemblage for the hydrocarbon which is partitionable into units of the composition C_6H_6 and have described the configuration of the molecule as thus derived. In the crystalline assemblage the carbon spheres of influence are arranged in columns, of which each link consists of three spheres in triangular contact; it has been concluded that these columns remain intact in the crystalline derivatives of benzene: the passage from the hydrocarbon to any derivative thus involves the moving apart of the columns of carbon

spheres and the insertion of the substituting groups in the spaces thus provided.

It is possible to test the correctness of the conclusions briefly referred to above by aid of crystallographic data for benzene derivatives. Compounds may be compared by means of their 'equivalence parameters,' which are the linear dimensions of parallelepipeds having volumes represented by the sums (W) of the valencies of the atoms composing the respective molecules, those linear dimensions being proportional to the crystallographic axial ratios. In the case of benzene, which crystallises in the orthorhombic system $a:b:c:=0{\cdot}891:1:0{\cdot}799$, the value of W is 30; the equivalence parameters calculated from these data are

$$x:y:z=3{\cdot}101:3{\cdot}480:2{\cdot}780.$$

The last of these values, $z=2{\cdot}780$, represents the height of two links in the columns of carbon spheres in the crystalline hydrocarbon; if, as has been suggested, these columns remain intact in the crystalline derivatives of benzene, the value 2·780 should recur amongst the equivalence parameters of the derivatives. This has been already shown to be the case in a long series of crystalline derivatives of picric and styphnic acids; the data now contributed enable the conclusion to be extended to the sulphonic derivatives of benzene described above.

The following table gives the equivalence parameters, x, y and z and the valency volumes, W, for the substances numbered in the above table of axial ratios:—

1.	W = 36.	$x:y:z=5{\cdot}787:2{\cdot}337:2{\cdot}674,\ \beta=95°\ 26'$.
2.	36.	$5{\cdot}796:2{\cdot}338:2{\cdot}676,\ \beta=96°\ 49'$.
3.	36.	$5{\cdot}761:2{\cdot}333:2{\cdot}692,\ \beta=95°\ 50'$.
4.	36.	$3{\cdot}409:3{\cdot}986:2{\cdot}661,\ \beta=95°\ 22'$.
5.	36.	$3{\cdot}095:4{\cdot}247:2{\cdot}779,\ \beta=99°\ 42'$.

The third equivalence parameter, z, calculated from the axial ratios and the valency volumes, in each case approximates to the corresponding value, $z=2{\cdot}780$, of benzene. The corresponding value in the case of the series of picric and styphnic acid derivatives examined by Jerusalem [1] varies between 2·660 and 2·788.

The axial ratios of the more complex benzene derivatives represented by the labile form of 1 : 4–dibromobenzene–2–sulphanilide and the ethylic 1 : 4–dibromobenzene–2–sulphonate do not, in the form stated above, immediately yield values approximating to 2·780 amongst their equivalence parameters. On dividing unit length along the axis b by two in the former case and multiplying it by two in the latter, the following equivalence parameters are, however, obtained in which the value 2·780 recurs:—

6.	W = 68.	$x:y:z=5{\cdot}327:\mathit{2{\cdot}782}:4{\cdot}653,\ \beta=99°\ 30'$.
7.	= 49.	$=2{\cdot}859:6{\cdot}410:\mathit{2{\cdot}679},\ \beta=90°\ 0'$.

The confirmation of Barlow and Pope's conclusion as to the existence of the columns of carbon spheres in crystalline benzene derivatives which Jerusalem obtained by the study of the picrates and styphnates may consequently be extended to the quite different class of derivatives dealt with in this report.

The Committee are indebted to Messrs. Colgate, Rodd and Runeckles, students in the Chemical Department of the Central Technical College, South Kensington, for assistance they have rendered in preparing and measuring compounds described in this report.

[1] *Trans. Chem. Soc.*, July 1909, p. 1275.

Electroanalysis.—Report of the Committee, consisting of Professor F. S. Kipping (*Chairman*), Dr. F. M. Perkin (*Secretary*), Dr. G. T. Beilby, Dr. T. M. Lowry, Professor W. J. Pope, *and* Dr. H. J. S. Sand.

During the year experiments have been carried out upon a new design of potentiometer, on the general simplification of apparatus and method for the electro-deposition of metals particularly by means of graded potential; and in connection with the electro-deposition of mercury upon gold, silver, platinum, and mercury cathodes.

In connection[1] with the latter part of the subject it has been found, when mercury is deposited on a gold electrode, that the results are invariably from 0.5 to 2.0 per cent. too high; the same applies also to electrodes of silver. The gold electrode employed was in the form of a flag, and had a total active surface of 0.5 square decimeter. As pure gold was found too soft for working purposes, an alloy containing 5 per cent. of platinum was used. Specially purified mercuric chloride-bromide, and sulphate were employed, but the results obtained were always too high. When a platinum gauze electrode was placed in series with the gold electrode and an identical solution employed, as a rule the metal deposited on the platinum was almost theoretically correct, although at times it was fractionally low.

In order to get more rapid deposition the gold electrode was placed in the field of a very powerful electro-magnet, but even though the time of deposition was reduced by one-tenth the results were still too high.

The silver cathodes consisted of coils of pure silver within which a platinum anode was rotated, but although the whole of the metal was frequently deposited in forty-five minutes, the results were almost always too high. The exact cause of the high results obtained was not ascertained, although it was at first supposed to be due to occluded hydrogen; this was practically proved not to be the case. It was finally shown that the only really satisfactory method for depositing mercury was to use a cathode of mercury. A new electrolysing vessel of quartz was designed for this purpose. This apparatus is a small quartz beaker capable of holding about 80 c.c. of solution, and has a siphon fused into it about 0.5 c.m. from the bottom. Mercury is placed in the vessel so as to just reach to the bottom of the siphon, and electrical contact is made with it by fusing a piece of iridium wire into the bottom of the beaker. The solution to be electrolysed is placed above the mercury and the spiral anode rapidly rotated (500-750 turns per minute). The mercury can be completely deposited out in from twenty minutes to half an hour. The solution is then siphoned off by pouring in water which causes the siphon to act. The pouring in of water is continued until the ammeter shows zero. The whole of the waste water is then allowed to flow away and is replaced by 90 per cent. alcohol, then by absolute alcohol, and finally by two washings of dry ether. The surface is then dried by blowing dry air over it for about ten minutes.

A very considerable amount of work has been done to make the

[1] F. M. Perkin, *Trans. Faraday Society.*

apparatus described by Dr. Sand (Trans. Chem. Soc. 91, 373 (1907) and 93, 1572 (1908) more portable and readily set up without sacrificing any of its essential features. The stand has been made completely portable by providing it with a special cap which hinders the mercury forming the connection between the stationary and moving parts from being split during transport. A special clutch has also been designed which allows the moving parts to be readily thrown in and out of gear with the motor without stopping the latter. Such an arrangement becomes necessary when it is desired to actuate several sets of apparatus from a single shaft driven by one motor, or when a small motor-generator is employed for the double purpose of supplying the current and rotating the electrode, or lastly, when a water or hot-air motor is employed which cannot be stopped instantly while the electrodes are in a wet state. All the apparatus for measuring the potential of the cathode has been assembled in a single portable potentiometer-box, which is also arranged to show the potential difference between the anode and the cathode. For this purpose it became necessary to design a special new form of portable capillary electrometer. A full description of all the apparatus referred to will be published shortly. It was exhibited to Section 1 of the International Congress of Applied Chemistry.

Experiments are also in progress with anodes made partly of glass and partly of platinum, and with cathodes of metals other than platinum.

A very careful study has also been made of the composition of the deposit of lead peroxide obtained during the analysis of lead solutions. Results differing by more than 1 per cent. have been found in the laboratories of Hollard. (Analyse des Bétaux (190) and Classen ('Quantitative Analyse durch Elektrolyse,' 5th edition, 1908, p. 125.) It has now been found that in a moist atmosphere lead peroxide will take up water at a temperature of about 200°, but will lose it exceedingly slowly at this temperature in a perfectly dry atmosphere. These facts are quite sufficient to explain the discrepancies observed. On the other hand, it has been found that lead peroxide deposited with a suitable current density at about 90-95° contains only about $\frac{1}{3}$ per cent. of water after drying with alcohol and ether. It is here desiccated as a result of electric endosmose, and this method of depositing is recommended as by far the most trustworthy and simple. These results will also be published shortly.

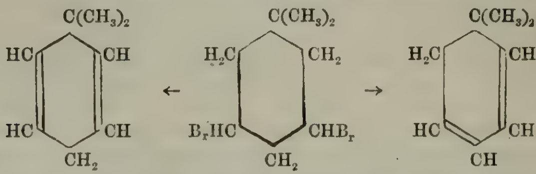
The Study of Hydro-aromatic Substances.—Report of the Committee, consisting of Dr. E. Divers (*Chairman*), Professor A. W. Crossley (*Secretary*), Professor W. H. Perkin, Dr. M. O. Forster, *and* Dr. H. R. Le Sueur.

1. *Nitro Derivatives of O-Xylene.*

In the last Report[1] mention was made of the fact that when the mixture of two isomeric dimethylcyclohexadienes, obtained by elimination of two molecules of hydrogen bromide from 3 : 5-dibromo-1 : 1-dimethylcyclohexane, was treated with a nitrating mixture, two substances melting at

[1] *B.A. Report*, 1908, p. 221.

115° and 71° were obtained. The methyl groups in the hydrocarbons are both attached to the same carbon atom, and in such cases it has been frequently observed[1] that the transformation into an aromatic substance



results in one of the methyl groups wandering into an ortho position, but never into a meta or para position. It was therefore presumed that the above-mentioned substances melting at 115° and 71° were trinitro-o-xylenes.

No trinitro-o-xylenes had, up to that time, been described, and experiments were therefore undertaken with the object of preparing these substances. The work has now been completed,[2] and has shown that the above-mentioned derivatives, melting at 115° and 71°, are the two possible trinitro-o-xylenes. In the course of the work all the mono-, di-, and trinitro-o-xylenes were isolated and described.

2. *Hydro-aromatic Ketones.* Part 1.—*Synthesis of trimethylcyclohexenone (Isophorone) and some homologues.*[3]

Chlorodimethylcyclohexenone contains a reactive chlorine atom, easily replaceable by an ethoxy group under the influence of sodium ethoxide, giving rise to the ethyl ester of dimethyldihydroresorcin.

Condensation takes place readily between chlorodimethylcyclohexenone and ethyl sodiomalonate. The product is not, as might have been expected, the substance having formula I., but consists of ethyl

$$(CH_3)_2C{<}\begin{array}{l}CH_2-CO\\ CH_2-C\end{array}{>}CH$$
$$\text{(I.)}\quad \begin{array}{l}|\\ CH(CO_2C_2H_5)_2\end{array} + C_2H_5OH = (CH_3)_2C{<}\begin{array}{l}CH_2-CO\\ CH_2-C\end{array}{>}CH$$
$$\text{(II.)}\quad \begin{array}{l}|\\ CH_2.CO_2C_2H_5\end{array} + CO(OC_2H_5)_2$$

dimethylcyclohexenoneacetate II, whose formation necessitates the elimination of a carbethoxy group, and this has been proved to take place with formation of ethyl carbonate.[4] The product of hydrolysis of this ethyl ester is trimethylcyclohexenone III, identical with isophorone.

$$(CH_3)_2C{<}\begin{array}{l}CH_2-CO\\ CH_2-C\end{array}{>}CH + H_2O = (CH_3)_2C{<}\begin{array}{l}CH_2-CO\\ CH_2-C\end{array}{>}C + CO_2 + C_2H_5OH$$
$$\begin{array}{l}|\\ CH_2.CO_2C_2H_5\end{array} \qquad \text{(III.)}\ \begin{array}{l}|\\ CH_3\end{array}$$

As, however, it gives only one oxime melting at 78°, whereas the isophorone prepared from acetone gives two oximes, melting at 75° and

[1] *J.C.S.*, 1904, **85**, 264; 1906, **89**, 875.
[2] *Ibid.*, 1909, **95**, 202.
[3] Crossley and Gilling, *J.C.S.*, 1909, **95**, 19.
[4] *Proc. C. S.*, 1909, **25**, 96.

100° respectively, the latter is probably a mixture of isomeric trimethylcyclohexenones. Dimethylethyl- and dimethylpropylcyclohexenones have also been prepared by the condensation of chlorodimethylcyclohexenone with substituted malonic esters; but as the yields of condensation products diminish rapidly with increase in molecular weight of the substituted malonic ester employed, the reactions are of no great value for the production of the higher homologues of isophorone.

3. *The so-called* 1:1-*dimethyl-*Δ2:5-*cyclohexadiene of Harries and Antoni.*[1]

A further inquiry into the properties and behaviour of the 1:1-dimethylcyclohexadiene of Harries and Antoni has shown that this hydrocarbon is a mixture of the 1:2- and 1:3-dimethylcyclohexadienes, and very probably contains none of the isomeric hydrocarbon with the two methyl groups in the 1:1-position.

Incidentally it has also been noted that the 1: 3-dimethylcyclohexadiene, prepared by the dehydration of methylheptenone, is a mixture of m-xylene, 1: 3-dimethylcyclohexene and 1: 3-dimethylcyclohexadiene.

The Transformation of Aromatic Nitroamines and Allied Substances, and its Relation to Substitution in Benzene Derivatives.—Report of the Committee, consisting of Professor F. S. KIPPING (*Chairman*), Professor K. J. P. ORTON (*Secretary*), Dr. S. RUHEMANN, Dr. A. LAPWORTH, *and* Dr. J. T. HEWITT.

I. *Transformation of Nitroaminobenzenes into Nitroanilines.*

IN last year's Report[2] a summary was given of the study of the conditions under which nitroaminobenzenes change into nitroanilines. It was shown for solutions of nitroamines, (i) that all acids accelerate (or initiate) the change ; (ii) that the efficacy of different acids bears a relation to their activities in other reactions ; (iii) that the rate of change is proportional to the square of the concentration of the acid ; (iv) that the transformation was always accompanied by the appearance of nitrous acid, and the conversion of nitroamine into diazonium salt.

II. *Transformation of Chloroaminobenzenes into Chloroanilides.*

(With W. C. EVANS, B.Sc., and W. J. JONES, B.Sc.)

The results obtained in the case of the nitroamines have led us to make a study of the similar transformation of acylchloroaminobenzenes into chloroacetanilides : $C_6H_5NCl.Ac \rightarrow Cl.C_6H_4.NH.Ac$.

This change offers a very marked contrast to that of the nitroaminobenzenes, as hydrochloric acid appears to occupy a peculiarly privileged position, which was originally recognised by Armstrong, in bringing about this change.

[1] Crossley and Renouf, *J.C.S.*, 1909, 95.

[2] *B.A. Report*, 1908, p. 115.

The mechanism of this transformation was investigated by Blanksma,[1] who ascertained (i) that it was apparently a reaction of the first order; (ii) that the speed was proportional to the square of the concentration of the hydrochloric acid; (iii) that in aqueous acetic acid solution the speed increased with the concentration of the acetic acid.

Recently Acree,[2] since we started work on this subject, has elaborated Blanksma's work, and has brought forward an hypothesis to account for the proportionality of the velocity of the change to the square of the concentration of the catalyst. He believes that the formation of a salt, $\mathrm{Ar.N}\begin{smallmatrix}\diagup\mathrm{Ac}\\ \mathrm{Cl}\\ \mathrm{Cl}\\ \diagdown\mathrm{H}\end{smallmatrix}$, from the chloroamine and the hydrochloric acid is the necessary intermediate step in the change. This suggestion was first made by Orton.[3] The complete ionisation of the hydrochloric acid requires that the concentration of the salt should be proportional to the square of that of the acid. It is however difficult to see why on this view hydrochloric acid should be the only catalyst. In fact, Acree believes his experiments show that other acids (sulphuric acid, &c.) or chlorine or bromine can act as catalysts, although in an inferior degree.

In our experiments we used instead of the unsubstituted chloroaminobenzene, acetylchloroamino-*p*-chlorobenzene, the speed of the transformation of which is far less than of the unsubstituted compound. The results are summarised in the following:—

1. Hydrochloric acid is the only catalyst.

(*a*) Hydrofluoric, sulphuric acids, &c., have no effect; hydrochloric acid can always be detected when a change begins in the presence of these acids.

(*b*) Chlorine and bromine are without effect until hydrochloric acid is formed.

(*c*) Hydrobromic acid reacts with the chloroamines in glacial acetic acid quantitatively, thus:—

$$\mathrm{Ar.NCl.Ac + HBr = Ar.NH.Ac + BrCl}.$$

This primary change is followed by rapid bromination (dimolecular reaction).

The interaction between hydrochloric acid and a bromoamine is similar:

$$\mathrm{Ar.NBr.Ac + HCl = Ar.NH.Ac + BrCl},$$

and is followed by an equally rapid bromination.

In dilute acetic acid, 90 per cent. and less, the reaction is:—

$$\mathrm{Ar.NCl.Ac + 2HBr = Ar.NH.Ac + HCl + Br_2},$$

which is followed by a slow bromination.

2. Hydrochloric acid reacts with the chloroamine establishing the equilibrium:

$$\mathrm{Ar.NCl.Ac + HCl \rightleftarrows Ar.NH.Ac + Cl_2}.$$

In glacial acetic acid the reaction is complete from left to right. As the acetic acid is diluted the left-hand side of the equation appears; in 90 per cent. acetic acid an equilibrium constant can be calculated.

[1] *Receuil des Trav. Chim.*, 1903, **22**, 290.
[2] *Amer. Chem. Jour.*, 1907, **38**, 258. [3] *Proc. Roy. Soc.*, 1902, **71**, 156.

In 65 per cent. acetic acid an equilibrium constant is obtained only when the reaction is represented as :—

$$Ar.NCl.Ac + H^{\cdot} + Cl' \rightleftarrows Ar.NH.Ac + Cl_2 ;$$

that is, the equilibrium constant is proportional to the second power of the concentration of the acid.

In 50 per cent. acetic acid, at a concentration of 0·025 gram molecules per litre, the system is represented by the left-hand side of the equation, chlorine and anilide only appearing at higher concentrations.

3. Measurements of the velocity of the formation of the chlorinated anilide show :—

(*a*) In glacial acetic acid the reaction is apparently dimolecular. If the concentration of the hydrochloric acid is small relative to the chloroamine the reaction becomes apparently monomolecular, and its speed is proportional to the square of the concentration of the hydrochloric acid.

(*b*) As the acetic acid is diluted to 95 per cent., the speed of the chlorination increases proportionately to the quantity of water added.

As the proportion of water is further increased the velocity of the reaction falls, becoming scarcely perceptible in 30 per cent. acetic acid.

(*c*) In aqueous acetic acid containing 70 to 90 per cent. acetic acid, there is no simple relation between the velocity of the change and the concentration of the hydrochloric acid. Below 65 per cent. acetic acid the velocity is proportional to the square of the concentration of the catalyst.

Topographical and Geological Terms used locally in South Africa.—Report of the Committee, consisting of Mr. G. W. LAMPLUGH (*Chairman*), Dr. F. H. HATCH (*Secretary*), Dr. G. CORSTORPHINE, *and* Messrs. A. DU TOIT, A. P. HALL, G. KYNASTON, F. P. MENNELL, *and* A. W. ROGERS, *appointed to determine the precise Significance of Topographical and Geological Terms used locally in South Africa.* (*Drawn up by the Secretary.*)

OWING to the absence of the Secretary (Dr. F. H. Hatch) in South Africa, no further compilation could be got ready for publication this year. After consultation with other members of the Committee, however, the Secretary proposes the following emendations in definitions or spelling of terms in the list published last year. The Committee ask for reappointment.

Duin, plural *duine*

A sand dune.

Gouph (pronounced ' cope ')

A Bushman word, meaning 'as dry as can be,' applied to a portion of the Western Karroo.

Kasteel (literally Castle)—

A high peak or ridge, *e.g.*, Riebeck's Kasteel.

Kloof—

The head of a valley, with steep sides.

Kolk—

A hole in a river course.

Poortje—

A little poort.

Punt—

(i) A point on the coast, or (ii) a spur of a mountain.

Rug, plural *Ruggen*—

A ridge or series of ridges. The 'Ruggens,' in Cape Colony, is a plain cut up by rivers.

Investigation of the Fauna and Flora of the Trias of the British Isles.—Seventh Report of the Committee, consisting of Professor W. A. Herdman (*Chairman*), Mr. H. C. Beasley (*Acting Secretary*), Mr. E. T. Newton, Professor A. C. Seward, Mr. W. A. E. Ussher, Professor W. W. Watts, *and* Dr. A. Smith Woodward. (*Drawn up by the Acting Secretary.*)

[Plates III. and IV.]

In presenting this Report your Committee have first to express their deep sense of the loss sustained in the lamentable death of their Secretary, Mr. Joseph Lomas, F.G.S., to whom their successful working has been mainly due. To the enthusiasm of youth he added the judgment and experience of middle age, and to his friendly and genial disposition and unfailing readiness to help others we are indebted for the assistance of workers outside the Committee. His powers of observation and description, devoted as they were in recent years to the study of the Trias, more especially of the probable conditions under which it was formed, enabled him to contribute two Reports embodying results of his own work, and it was in the prosecution of such research as that your Committee was formed to promote that Mr. Lomas met his untimely end.

During the past year your Committee have watched for further opportunities of research, but the new material has been confined to a few remains of Rhynchosaurus which, as far as examination has at present gone, present no exceptional features, and a few other remains which have been too recently obtained to be reported on at this meeting.

Mr. A. R. Horwood gives a further instalment of his 'Bibliography of the Keuper,' bringing it to 1908, and Mr. Beasley a description of a new form of footprint. Mr. Watson adds a description of the

Rhynchosaurian skull in the Manchester Museum mentioned in the last Report.

Since their appointment in 1902 your Committee have endeavoured to promote and record original research in connection with the Triassic Fauna and Flora, and to report on the description of new material or material hitherto undescribed. Also they have had in view the desirability of rendering the reference to existing material more easy for workers; and consequently lists of the Triassic Fossils in most of our principal museums (Reports 1904, 1905, and 1908) and of Fossils found in certain localities (Reports 1907 and 1908) and a Bibliography (Reports 1908 and 1909) have been included in the Reports. It is hoped these lists will be found of use. The names of the authors are a guarantee of the care with which the lists have been drawn up. There are still many other collections of which it is desirable to obtain a record.

As regards research itself your Committee are glad to have been able to record the completion of the reconstruction of the skeleton of *Rhynchosaurus articeps*, with the aid of material in the Shrewsbury Museum submitted to the experts of the British Museum (Natural History) for development (*see* Report 1906). Reports have also been made on several other recently discovered less nearly complete vertebrate remains. (*See* Reports 1906, 1907, and 1909.)

The paper by the late Secretary in the Report for 1905 dealing with Estheria, both recent and fossil, will aid in forming a correct idea not only of the surroundings of this Common Triassic invertebrate, but of the general conditions prevailing in Britain in Triassic times.

The reports (*see* all years 1903 to 1909) on the footprints of vertebrates and supposed tracks of invertebrates, and the attempt to classify them, may prove useful when more of their remains have come to light.

The Trias of South Devon has so far been but slightly dealt with, but the description and figure of the Section E. and W. of Sidmouth by the late Mr. Hutchinson have been reproduced in the Report for 1905.

The Committee desire to record their thanks to the following gentlemen, who, though not on the Committee, have kindly aided the work by the contribution of most valuable lists and reports, viz., Messrs. H. A. Allen, A. R. Horwood, L. J. Wills, and D. M. S. Watson, and the Rev. H. H. Winwood.

In existing circumstances your Committee do not ask to be reappointed, but, in view of the large amount of work still to be done, may be allowed to express a hope that this research may be still further prosecuted in the future under the auspices of the British Association.

Report on Footprints from the Trias. Part VI. By H. C. Beasley.

A number of very imperfect examples of a large broad footprint of unusual form have been seen during the last few years at Storeton, but have been too imperfect for description. Within the last six months a few more perfect have been seen. The print shows four short stout toes, their length being only about three-quarters their breadth. The print itself is about 15 cm. in width, and length 12 cm., but the posterior margin is not defined. At about that distance from the termination of the toes it narrows to about 6 cm., and the print is often continued for a few inches the same width till it merges into the surface of the slab.

The print as a whole is very symmetrical, the two middle toes are about the same size, and the two outer rather smaller, but similar to each other; the narrow hinder part of the print probably represents a portion of the leg.

The sole is covered with ridges or folds following the outline of the toes, but on the palmar surface they are more or less parallel to the axis of the foot. Some doubt must exist as to their origin and whether they really represent the loose integument of the foot.

One or two fairly perfect casts of deep impressions are from the Lower Keuper at Storeton, and an exactly similar print is in the Salford Museum from Lymm, and they might be compared with some less well-defined prints in the Warwick Museum 'from the Upper Keuper.'

So far great uncertainty exists regarding it, both as to whether it represents the *pes* or *manus*. Further material may show us this, also if there is a trace of a fifth digit. The possibility of its having been formed by any movement of such a foot as A 2 or K has been considered, but it is highly improbable. It is advisable that this print should be recorded (bearing in mind that it is the print only, and not the foot, that is being described) under a special letter.

P $\frac{1}{10}$

P, a four-toed print, breadth rather greater than length, toes short and stout, breadth at base exceeding length. Breadth of foot greatest at root of toes, narrowing rapidly posteriorly till it joins the leg. No defined posterior margin. Two inner toes alike, two outer toes also alike, but rather smaller. (Plate III.)

It is perhaps now advisable to summarise shortly the Reports on Triassic footprints. A good deal of new material has been examined since the earlier Reports were issued, and some qualifications or corrections may be necessary.

The reasons for not giving generic and specific names to the various forms which were expressed in the earlier Reports still hold good. The identification of the animals who left the prints with any whose remains have been preserved is unfortunately not yet possible, and how far the different forms represent different species of animals is not absolutely certain. Under these circumstances the specific naming of the prints would tend to error and confusion, which would be a worse result than the slight inconvenience incidental to the system of identification by letters and numbers. It is still necessary to deal with them as prints only. The greater number fall into three groups, which have been called respectively *Cheirotheroid*, *Rhynchosauroid*, and *Chelonoid*, mostly represented by what appears to be the print of a hind foot.

Cheirotheroid prints have five toes, of which the middle one is the longest and the fifth the shortest, and this is usually curved outwards. The palmar surface is about equal in area to that covered by the toes, though usually only a portion is shown in the print. To this group belong forms A 1 to 4, B 1 and 2, K and L.

The four forms A 1 to 3 and K form a complete series where the toes I. to IV., which in A 1 are somewhat longer proportionately than the fingers of the human hand, gradually become shorter and broader, and the V. toe decreases in size till in K there are four short broad toes, and there is no trace of the impression of V.

Since the four forms just referred to were first described another form, A 4, has been found varying in a different way from A 1, which otherwise it strongly resembles; the IV. toe in A 4 is relatively shorter, and generally carries a longer and more powerful nail than do the other toes. Accompanying this feature is a very different print of the manus; in A 1 and 2 the manus is about half the size of the pes and has five widely spread digits and forms a short broad print. In A 4 the print of the manus is very much smaller, has four very short broad digits, with occasionally a very uncertain trace of a fifth. A 4, however, resembles A 1 in having the skin of both pes and manus covered with small tubercles. A 4 has been found in series on the same slab with prints of A 1. It has so far only been found at Storeton, but on slabs raised there at intervals of several years.

Nothing has been found to indicate that these variations in form have been caused by difference in the material in which the first impressions were made; in fact, this is disproved by the different forms having been found in close proximity to each other on a perfectly uniform surface. Neither is there any indication of their occurring on different horizons.

It may be worth noting that the forms A 1 to 4 are seldom, if ever, found at Runcorn, whilst they are common a few miles east and west, and that whilst A 2 is common on Lymm and Warrington slabs, it is rather rare at Storeton. The beds at each place are about the same age, although it seems difficult to correlate them with each other. There would seem to be little probability of a continuation of the same bed for any great distance if, as is now generally held to be the case, the beds represent the bottoms of isolated, somewhat temporary, pools or lagoons.

It should also be borne in mind that no large extent of the surface of the footprint beds is exposed in quarries in the course of several years, and the prints of one or two species that happened to go to the water together have been seen, whilst the prints of other species may be hidden from us a few yards off on exactly the same horizon.

The two small prints B 1 and 2 have not been recognised in any new material, neither has the small print 'L,' which, though much smaller, resembles the pes of A except that there is no trace of the first or inner toe. The manus resembles that of A 4, but in the very few examples we have, only three digits are seen. The only example of this print in series is in the British Museum (Natural History) from Storeton, whence it must have been obtained some sixty years ago. A single print of the pes was found at Storeton a few years since, and another came from Guy's Cliff, Warwick, so they cannot be the tracks of one abnormal individual.

The Rhynchosauroid prints have five toes, little or no palmar surface, and the fourth toe the longest. To this group belong D 1 to 7 and E.

D 1 seems to be the most common form, and to approach nearest to what might be expected from *Rhynchosaurus articeps*. D 2 is much like it, but the toes are narrower and not so generally curved. It is very seldom that in either form there is any trace of the impression of a web.

A webbed foot would leave some trace of the web in all but very exceptional instances. However, on a slab in the British Museum (B 295) there is what appears to be a distinct web, and, as pointed out by Mr. D. G. S. Watson, there is another in the Manchester Museum.[1] In

[1] Mr. Watson's paper, 'Some Reptilian Tracks from the Trias of Runcorn,' presented at the June meeting of the Geological Society, not yet printed.

both cases the foot is very like D 1. The digits are not spread and are very unlike D 4, from Upper Keuper of Shrewley, which is distinctly webbed. As regards the other forms there is nothing to add to the Report. As a whole this group would come very near *Saurichnites lacertoides*, as described by H. B. Geinitz in his 'Dyas or Permian Formation,' Leipzig, 1861, page 5; but no attempt has been made in this report to trace the relation of British footprints to those of the Continent.

The Chelonoid prints, in some respects resembling the prints described by the pioneers of ichnology as those of tortoises, form the third group. They may be described as short, broad prints, with short toes and strong claws, and with the palmar surface forming the larger part of the area of the print. They have been distinguished by the letter F.

F 1 is the simplest form, being merely an oval rounded surface with four or five dots representing nailmarks a short distance beyond the margin on one side. In F 2 the place of the oval marking is taken by a moulded surface giving some indication of the position of the bones of the foot, and there are five short clawed digits. F 1 may probably be the impression of such a foot as F 2 on rather hard mud. F 3 has rather longer digits than F 2, and it is uncertain if the manus has more than four that have left traces.

All these prints when seen in series are found to have a very broad track. The print of the pes is frequently imposed on that of the manus of the same side; at other times the pes and manus are near to each other.

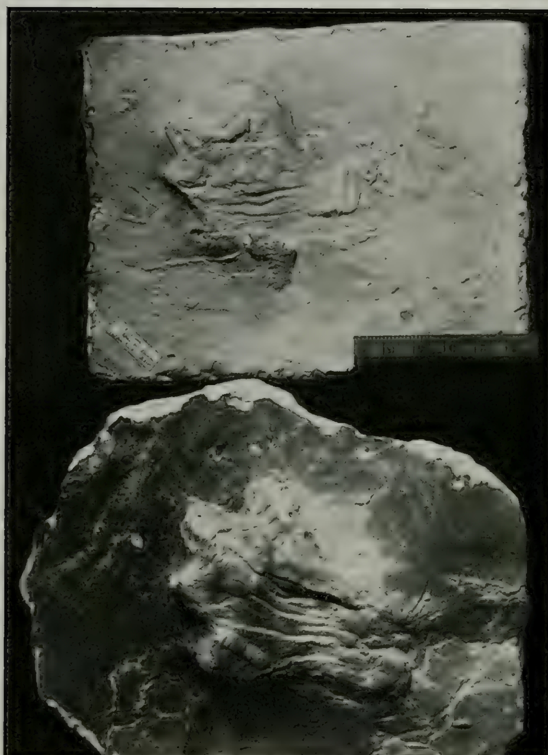
The prints of this group differ widely from most of the other two groups. A distant resemblance led to a careful comparison with some of the prints from Corncockle Quarry, Dumfries, in beds at one time thought to be in the Trias, but now generally considered Permian. The comparison showed that none of our Triassic prints were at all identical with those figured in Jardine's 'Ichnology of Annandale.'

Within the last few months Mr. Geo. Hickling has published a paper on British Permian footprints,[1] in which he goes thoroughly into this question, and comes to the conclusion that the footprints from the Trias are quite unrepresented in the Permian of Dumfries, Penrith, Nottinghamshire, or South Devon, as far as at present explored. As previously noted, there are several forms which do not readily fall into either of the three groups. These have been described as C and O in Report 1906, I in Report 1904, and P in the present Report, but no further knowledge concerning them has been yielded by new material. The print O is very interesting, as in some respects like the New England prints, and it is hoped that a further examination of the Hollington quarries may result in obtaining further examples.

It is noteworthy that no prints have been recorded that might seem to be intermediate between the three groups, but it is still possible that such may yet be found when the innumerable small prints covering slabs in various collections have been more thoroughly examined.

The question of the possibility of various forms resulting from the same foot being impressed on mud of differing consistency has been frequently referred to, and it is hoped that observations and experiments now in progress may lead to good results.

[1] 'British Permian Footprints,' *Memoirs Manchester Lit. Phil. Soc.*, vol. liii. part 3 (June 18, 1909).



2.

1.

Illustrating the Seventh Report on the Investigation of the Fauna and Flora of the Trias of the British Isles.

Note.

CONTENTS OF REPORTS ON FOOTPRINTS.

Explanation of Plate III.

Two natural casts of footprints described as 'P' in present report from the Lower Keuper of Storeton in H. C. Beasley's collection.

No. 1 is in high relief, about 3 inches; No. 2 not more than 1½ inch. There are other markings of uncertain origin on both slabs. The scale shown is one of 6 inches.

On a Skull of Rhynchosaurus in the Manchester Museum.

By D. M. S. WATSON, *B.Sc.*

Rhynchosaurus is probably the best known of all the Triassic Rhynchocephalia, and an excellent account of its osteology, by Dr. A. Smith Woodward, was published in the Report of this Committee presented at the York meeting of the Association. This report shows that our knowledge of the base and back of the skull is defective, and as a specimen in the Manchester Museum shows some new features in this region, it seems worthy of some description.

This skull was collected by Mr. G. C. Spence in 1895 from the quarry at Grinshill, which is the type locality. Mr. Spence roughly developed the anterior portion of the palate, and in 1907 presented the specimen to the Museum. When I first saw it, it was contained in two small blocks of coarse sandstone, which fitted together. One of these blocks retains the nasals and premaxillæ, and is separated from the other by a split, which cuts the palate about 1.5 cm. in front of the transpalatines. The other block contains the main mass of the skull, and now shows the whole of both upper and under surfaces, together with the posterior surfaces of the quadrates.

The matrix is a coarse and very hard sandstone, the bone is extremely soft, so much so that it falls away as dust, after being exposed for a few days, when subjected to the jarring inevitable to the process of development; the skull is thus very largely represented by an internal cast, to which a certain amount of bone remains attached, forming a thin white layer; nevertheless, certain points are exceedingly well displayed.

I am unable to add anything to the account given by Dr. Woodward of the anterior part of the skull.

The brain-case widens out posteriorly, and lateral processes are given off which underlie the corresponding inwardly directed processes of the squamosal. There is, however, certainly a bone overlying the squamosal, and apparently running straight across from side to side without any connection with the parietals: this bone is probably a separate ossification, the epiotic of the Stegocephalian skull.

The squamosal is a triradiate bone; it differs from that figured by

other writers in the skull of *Rhynchosaurus articeps* in having a larger area. The internal ramus extends in, under the epiotic on both sides, and is hence not well exposed. The anterior ramus is about 1.7 cm. long and at least 1 cm. wide at its base; it is well shown on the left side to underlie the posterior ramus of the postorbital. The inferior ramus also expands into a plate of bone proximally; this is confluent with that formed by the anterior ramus; there is hence a very considerable area of bone over the postero-lateral corners of the upper surface of the skull. The figures of Owen and Smith Woodward's restored drawing represent the skull of *Rhynchosaurus articeps* as very slender in this region, and it is hence possible that the Manchester skull really represents a distinct species; I am, however, very unwilling to found a new species on this one specimen.

The relation of the squamosal to the quadrate and the quadratojugal is not now well seen in the specimen, mainly on account of the crumbling of the bone in this region. I was able to see during development that there was no foramen between the quadrate and the quadratojugal as there is in Sphenodon; a specimen in the Elgin Museum shows that Hyperodapedon resembles Rhynchosaurus in this respect. Both quadrates are now exposed from the back in the Manchester Rhynchosaurus skull, but are badly preserved, the bone being very soft and friable.

The lower temporal arcade is represented by a misplaced posterior ramus of the jugal, which forms a thin strip of bone about 3 cm. high and ·7 cm. thick. The quadratojugal can be seen as a forward projection from the distal end of the quadrate, but it is not well exposed.

The anterior portion of the palate is badly preserved; the teeth, for example, have been destroyed. There are certain differences in this region between this specimen and that figured by Huxley and Smith Woodward; for example, a length of 30 mm. in the new specimen corresponds to 50 mm. in Huxley's specimen, which measures about 42 mm. across the transpalatine region, as against 37 mm. in the new skull; thus the snout of the new specimen is blunter than that of Huxley's skull. This difference may be specific or may merely depend on differences of sex or age.

The important new features presented by this specimen concern the pterygoids and basis cranii.

The right pterygoid is almost completely preserved and exposed. The anterior ramus cannot be distinguished from the palatine; the external ramus forms a nearly vertical plate directed forward and outward at an angle of about 45° to the basicranial axis. This unites with the transpalatine, the two forming the usual downwardly directed process.

The transpalatine forms the posterior edge of the palate and joins the maxilla probably near its junction with the jugal.

The anterior and exterior rami of the pterygoid pass back, forming a vertical plate of bone over a centimetre deep, which joins on to the pterygoid process of the basisphenoid. How much of this plate is pterygoid and how much basisphenoid I cannot say. The plate is 3 mm. in antero-posterior length, and very thin. From its posterior and ventral margin is given off the posterior ramus, which is a narrow bar only 2 mm. by 1 mm. in section, passing back to the quadrate, a distance of some 20 mm. Its junction with the quadrate is not exposed, and it is possible that it is slightly dislocated at this point.

FIG. 1.

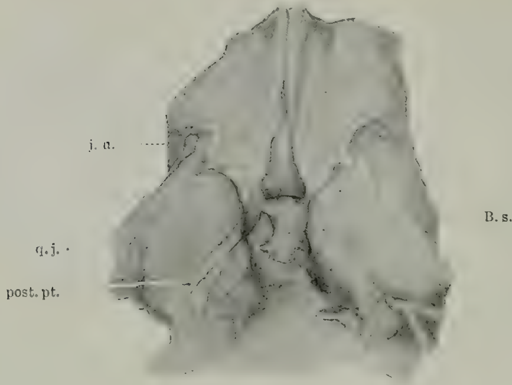


FIG. 2

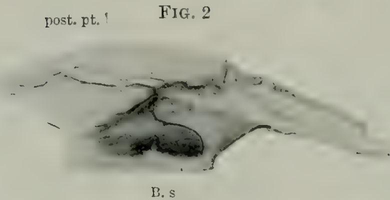
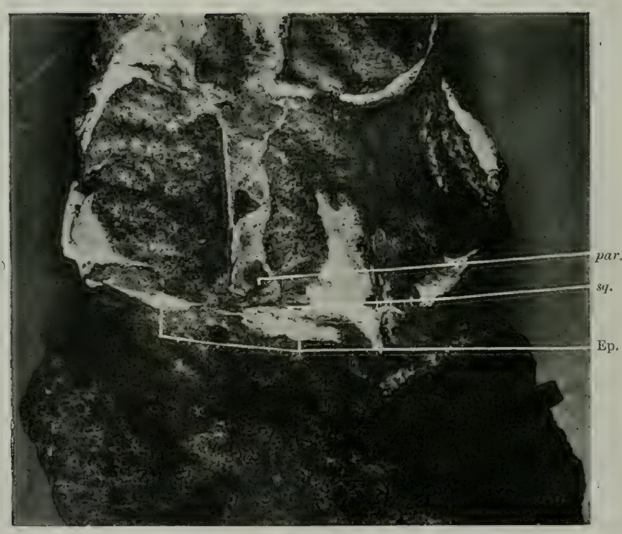


FIG. 3.



Illustrating the Seventh Report on the Investigation of the Fauna and Flora of the Trias of the British Isles.

The basisphenoid is exposed as a bone nearly 1 cm. wide between the down-turned pterygoid processes. This bone contracts behind to a width of about 5 mm.; behind this it has two lateral wings, which are, however, badly preserved and exposed. These wings probably correspond with the two knobs which occur in Sphenodon just before the junction of the basisphenoid and basioccipital. The small piece of bone immediately behind is the basioccipital. This is 1.5 mm. long, and is succeeded by the atlas, which is not easily distinguished from it, being represented mainly by a hole. The palate, as a whole, much resembles that of Sphenodon, the chief differences being as follows:

(1) There appears to be no suborbital foramen in front of the transpalatine, whereas in Sphenodon there is a small one; this difference is not a very important one as is shown by the similar variation in Sauropterygians.

(2) In the great height of the pterygoid process and attached pterygoids Rhynchosaurus differs considerably from the condition in Sphenodon.

(3) The great distance between the two pterygoids in this region in Rhynchosaurus is also a conspicuous difference from the other genus.

(4) The fact that the posterior ramus of the pterygoid is only a slender bar in the Triassic genus renders its appearance different from that of Sphenodon.

The palate of Rhynchosaurus resembles strongly that of Hyperodapedon in certain respects, whilst differing from it more widely than does that of Sphenodon in others.

Apart from the dentition, the chief differences between the two Triassic genera are as follows:—

(1) In Hyperodapedon the pterygoids meet in the middle line and appear completely to conceal the basisphenoid from a ventral view; this is a pronounced difference from Rhynchosaurus, in which the whole of the basis cranii can be seen from below.

(2) In Hyperodapedon the pterygoids appear to be only just below the main ventral surface of the basisphenoid, and are possibly in actual contact with it, whilst in Rhynchosaurus they are carried down on two long processes to about 1 cm. below that level.

In these two respects Sphenodon seems to be exactly between the fossil genera. On the other hand, these latter agree in the absence of any infraorbital foramen and of the foramen between the quadrate and the quadratojugal. They also agree in the very pronounced downward curve of the premaxillæ, which in the recent Sphenodon bears two teeth and is not itself appreciably decurved.

On the whole of the evidence, I think that Rhynchosaurus and Hyperodapedon should not be placed in the same family, but that they should be included in a super-family, which would most probably also include Stenometopon, but not Sphenodon.

Explanation of Plate IV.

FIG. 1.—Under surface of the skull of Rhynchosaurus in the Manchester Museum. Nat. size.

ju.	Anterior end of the misplaced jugal.
q.j.	The quadratojugal.
post. pt.	The posterior ramus of the pterygoid
B. s.	The basisphenoid.

FIG. 2.—The right side of the same skull as it would appear if bisected by a sagittal section and viewed from the middle line.

To show that the basis cranii lies far below the level of the palate. Reference letters as in fig. 1.

FIG. 3.—Photograph of the upper surface of the back of the skull. × $1\frac{1}{2}$ approx. To show the epiotic (Ep.) overlying the squamosals (*sq.*), which in turn overlie the parietals (*par.*).

Bibliographical Notes upon the Flora and Fauna of the British Keuper. *By* A. R. HORWOOD.

Lists dealing with the palæontology of the Leicestershire Upper Keuper and some neighbouring localities, and a bibliography relating to the same, were published in the Trias Report for 1907. In the last year's Report (1908) a list of the fossils from certain counties, which had not so far found a place in these Reports, was published, together with a bibliography of works relating to the flora and fauna from 1826 to 1876. The present communication is complementary to the two former lists, bringing the literature up to date from 1877 onward, and bringing together in one accessible bibliography all the works included in the Reports not so far arranged chronologically; and to these are added a number of papers not hitherto noted therein. Furthermore, the analysis of the palæontology of each work given at the end will serve, it is hoped, as a useful summary of the subject-matter in this connection.

In view of the fact that certain beds previously classed as Permian exhibit a typical Triassic vertebrate fauna, as remarked by Mr. H. A. Allen (Trias Report, 1908), some of the records which were regarded as referring to the Permian are included here. At the same time, the fact must not be ignored, in questions of this kind, that footprints resembling Triassic footprints have been discovered in the Permian beds of Mansfield,[1] Nottinghamshire, and in the Lower Sandstones of the Exeter district.[2] Indeed, there is, according to Mr. G. Hickling, some doubt as to whether the Elgin sandstones are not also Permian,[3] though Dr. F. von Huene[4] correlates these latter with the Dolomitic Conglomerate and German Lettenkohle (Lower Keuper).

1. Agassiz, L.—1833-1844 'Recherches sur les Poissons Fossiles,' ii. pt. i p. 303. *Palæoniscus catopterus* (Ag.), Keuper, Roan Hill, Tyrone.

2. Riley, H., and S. Stutchbury.—1836 'A Description of Fossil remains of three distinct Saurian animals recently discovered in the Magnesian Conglomerate near Bristol' ('Geol. Trans.,' v. 2nd series, 1836, p. 349). *Palæosaurus platyodon* (R. and S.), *P. cylindrodon* (R. and S.), and *Thecodontosaurus* sp., Magnesian Conglomerate, Durdham Down.

3. Buckland, Rev. W.—1837 'Geology and Mineralogy considered with reference to Natural Theology,' 2nd edition (vol i. pp. 259-266; vol. ii. pl. 26). *Cheirotherium*, Trias, Dumfries.

4. Egerton, Sir P. de Grey.—1838 'On two casts of Impressions of the Hind Foot of a gigantic Cheirotherium from the New Red Sandstone of Cheshire' ('Proc. Geol. Soc.,' iii., p. 14). *Cheirotherium*, Trias, Tarporley.

5. Ward, Dr. O. D.—1839 'On Footprints and Ripplemarks of the New Red Sandstone at Grinshill, Shropshire' ('Brit. Assoc. Rep.'). (?) *Rhynchosaurus*, Lower Keuper, Grinshill.

[1] *Quart. Journ. Geol. Soc.*, vol. lxii. 1906, pp. 125-131.

[2] *Ibid.*, vol. lxiv. 1908, pp. 496-500 and pl. li.

[3] *Mem. Manch. Geol. Soc.* 1909, paper in press.

[4] *Geol. Mag.* 1908, pp. 98-99.

6. Owen, Sir R.—1842 'Description of an Extinct Lacertilian Reptile, *Rhynchosaurus articeps*' ('Trans. Camb. Phil. Soc.,' xii. pp. 355-369, pl. lv., vi.). *Rhynchosaurus articeps* (Owen), Lower Keuper, Grinshill.

7. Agassiz, L.—1844 'Recherches sur les Poissons Fossiles du Vieux Grès Rouge' (p. 139). *Stagonolepis Robertsoni* (Ag.), Trias, Lossiemouth.

8. Black, Dr. J.—1846 'Observations on a Slab of New Red Sandstone from the Quarries of Weston, near Runcorn, Cheshire. Certain Impressions of Footprints in other marking' ('Quart. Journ. Geol. Soc.,' ii. p. 479). *Chelone subrotundus* (Morton), Lower Keuper Sandstone, Weston.

9. Cunningham, J.—1848 'Proc. Liverp. Lit. and Phil. Soc.,' i. *Cheirotherium minus* (Sickler), Lower Keuper, Flaybrick Hill, Birkenhead.

10. Lloyd, Dr. T.—1849 'Rep. Brit. Assoc., Trans. Sects., p. 56. *Dasyceps Bucklandi* (Lloyd), Permian (?), Kenilworth.

11. Quenstedt, F. A.—1850 'Die Mastodonsaurier,' p. 16, pl. ii. fig. 2. On *Capitosaurus*.

12. Mantell, G. A.—1852 'Description of the *Telerpeton Elginense*, a Fossil Reptile recently discovered in the Old Red Sandstone of Moray, with Observations on supposed Fossil Ova; of Ova of Batrachians in the Lower Devonian Strata of Forfarshire' ('Quart. Journ. Geol. Soc.,' viii. pp. 100-5, pl. iv.). *Telerpeton elginense* (Mant.), Keuper, Elgin.

13. Egerton, Sir P. de G.—1854 'On a Fossil Fish from the Upper Beds of the New Red Sandstone at Bromsgrove' ('Quart. Journ. Geol. Soc.,' x. pp. 367-371, pl. xi.). *Dipteronotus cyphus* (Eg.), 'Bunter,' Bromsgrove.

14. Brodie, Rev. P. B.—1856 'On the Upper Keuper Sandstone (included in the New Red Marl) of Warwickshire' ('Quart. Journ. Geol. Soc.,' xii. p. 374). Description of section of Upper Keuper Sandstone at Shrewley, Plants, *Estheria minuta* (Alberti), Mollusca, Footprints, Tracks, &c.

15. Brodie, Rev. P. B.—1858 'Notes on the Occurrence of a New Species of Fish in the Upper Keuper Sandstone in Warwick' ('Quart. Journ. Geol. Soc.,' xiv. p. 165). *Dictyopyge* (*Palæoniscus*) *superstes* (Eg.). Upper Keuper, Rowington.

16. Egerton, Sir P. de G.—1858 'On *Palæoniscus superstes*' ('Quart. Journ. Geol. Soc.,' xiv. p. 164, pl. xi. figs. 1-4). *Palæoniscus catopterus* (Ag.), Keuper, Roan Hill, Tyrone.

17. Hancock, A.—1858 'Remarks on certain vermiform Fossils found in the Mountain Limestone districts of the North of England' ('Ann. Mag. Nat. Hist.,' ii. 3rd series, p. 443)

18. Meyer, H. von.—1858 'Palæontographica,' vi. p. 228, pl. xxviii. fig. 1.

19. Howell, H. H.—1859 'The Geology of the Warwickshire Coalfield' ('Mem. Geol. Surv.,' p. 32). *Brcea eulassoides, Caulerpites oblongus, C. triangularis*, Permian (?), Meriden. (*Vide* also Phillips' 'Geol. of Oxford.' 1871.)

20. Huxley, T. H.—1859 'On the *Stagonolepis Robertsoni* (Agassiz) of the Elgin Sandstones, and on the recently discovered Footmarks in the Sandstones of Cummingstone' ('Quart. Journ. Geol. Soc.,' xv. pp. 440-460, pl. xiv. fig. 4). *Hyperodapedon Gordoni* (Huxley), Trias, Lossiemouth; Footprints, Trias, Cummingstone.

21. Huxley, T. H.—1859 in H. H. Howell's 'The Geology of the Warwickshire Coalfield, and the Permian Rocks and Trias of the surrounding district' ('Mem. Geol. Surv.'). *Labyrinthodon* sp., Lower Keuper, Cubbington. (*?Labyrinthodon Lavisi.*)

22. Owen, Sir R.—1859 'Notes on the Affinities of *Rhynchosaurus*' ('Ann. Mag. Nat. Hist.' [3], iv. pp. 237-238). *Rhynchosaurus articeps* (Owen), Lower Keuper, Grinshill.

23. Jones, T. R.—1862 'A Monograph of the Fossil Estheriæ' ('Pal. Soc.,' p. 57, pl. ii.). Records of Estheria.

24. Owen, Sir R.—1862 'Notice of a Skull and parts of the Skeleton of *Rhynchosaurus articeps*' ('Phil. Trans.,' pp. 466-467, pl. xxv.). *Rhynchosaurus articeps* (Owen), Lower Keuper, Grinshill.

25. Morton, G. H.—1863 ('Proc. Liverp. Geol. Soc.,' i.). *Cheirotherium stortonense*, suggested.

26. Huxley, T. H.—1867 'On a specimen of *Telerpeton elginense*' ('Quart. Journ. Geol. Soc.,' xxiii., Proc. pp. 77-84, text figures, A—E). *Telerpeton elginense* (Mant.), Trias, Lossiemouth.

27. Williamson, W. C.—1867 'Cheirotherium Footprint from the Base of the Keuper Sandstone, Daresbury' ('Quart. Journ. Geol. Soc.,' xxiii. pp. 56-7,

pl. iii. fig. i., and *ibid.*, xxii. pp. 534-5). Footprint of *Cheirotherium*, Lower Keuper, Daresbury.

28. Huxley, T. H.—1869 'On *Hyperodapedon*' ('Quart. Journ. Geol. Soc.,' xxv., Proc. pp. 138-152). *Hyperodapedon Gordoni* (Huxley), Trias, Elgin; Lower Keuper, Coton End; Keuper, Left Bank of River Otter, Budleigh, Devon.

29. Etheridge, R.—1870 'On the Geological Position and Geographical Distribution of the Reptilian or Dolomitic Conglomerate of the Bristol area' ('Quart. Journ. Geol. Soc.,' xxvi. pp. 174-192). *Thecodontosaurus, Palæosaurus*, Dolomitic Conglomerate, Bristol; *Hyperodapedon*, Devon.

30. Huxley, T. H.—1870 'On the Classification of the Dinosauria, with observations on the Dinosauria of the Trias' ('Quart. Journ. Geol. Soc.,' xxvi. pp. 32-51, pl. iii. fig. 4). *Thecodontosaurus cylindrodon* (R. and S.), Lower Keuper, Coton End; *Teratosaurus* (*Zanclodon*), Coton End.

31. Irving, Rev. A.—1874 'On the Geology of the Nottingham District' ('Geol. Mag.,' pp. 314-9). Footprints of *Cheirotherium*, Castle Donington, doubtless meant for Weston, and Colwick, near Nottingham.

32. Traquair, R. H.—1877 'On the Agassizian genera *Amblypterus, Palæoniscus, Gyrolepis*, and *Pygopterus*' (Quart. Journ. Geol. Soc., xxxiii. p. 567). *Dictyopyge catoptera* (Ag.), Keuper, Roan Hill, Tyrone.

33. Miall, L. C.—1878 'A Monograph of the Sirenoid and Crossopterygian Ganoids,' pt. i. ('Pal. Soc.,' p. 32, pl. v. fig. 2). *Ceratodus lævissimus* (L. C. Miall), Upper Keuper, Ripple, Worcestershire; Lower Keuper, Coton End, Warwickshire.

34. Sollas, W. J.—1879 'On some Three-toed Footprints from the Triassic Conglomerate of South Wales' ('Quart Journ. Geol. Soc.,' xxxv. pp. 511-516). *Brontozoum Thomasi* (Sollas), Trias Conglomerate, Newton Nottage, Glamorgan.

35. Nathorst, A. G.—1880 'On some Tracks of Invertebrates, &c., and their Palæontological Bearing' ('Kon. Svenska Vet. Akad. Handlingur.,' band 18, No. 7).

36. Hughes, T. McKenny.—1884 'Some Tracks of Terrestrial and Freshwater Animals' ('Quart. Journ. Geol. Soc.,' xl. p. 178, pl. 7-11).

37. Huxley, T. H.—1887 'Further Observations upon *Hyperodapedon Gordoni*' ('Quart. Journ. Geol. Soc.,' xliii. pp. 675-694, pl. xxvii.). *Hyperodapedon Gordoni* (Huxley), Trias, Lossiemouth; and on *Rhynchosaurus articeps* (Owen).

38. Newton, E. T.—1887 'On the Remains of Fishes from the Keuper of Warwick and Nottingham, with notes on their mode of occurrence by the Rev. P. B. Brodie and E. Wilson' ('Quart. Journ. Geol. Soc.,' xliii. pp. 537-543, pl. xxii.). *Semionotus Brodiei* (Newt.), Upper Keuper, Shrewley; Lower Keuper, Colwick, Notts.

39. Zittel, K. A. von.—1887-8 'Handbuch der Palæontologie,' iii. p. 203 and p. 404, f. 396). *Palæoniscus superstes* (Ag.), Trias, Tyrone; and on *Capitosaurus*.

40. Woodward, A. S.—1889 'On the so-called *Hybodus keuperinus* (Murch. and Strickl.), Palæichthyological Notes, No. 1 ('Ann. and Mag. Nat. Hist.' (6), iii. p. 297, pl. xiv. figs. 1-3) On *Acrodus keuperinus* (M. and S.), Worcestershire, Warwickshire.

41. Woodward, A. S.—1889 'On *Diplodus Moorei* sp. nov., from the Keuper of Somersetshire' ('Ann. and Mag. Nat. Hist.' (6), iii. p. 299, pl. xiv. figs. 4, 5). *Diplodus Moorei* (A. S. Woodw.), Keuper, Ruishton, Somersetshire.

42. Woodward, A. S.—1889 'Catalogue of Fossil Fishes in the British Museum' pt. i. p. 281. *Acrodus keuperinus* (M. and S.), Upper Keuper, Worcestershire; Pendock, Ripple, Burge Hill; and Shrewley and Rowington, Warwickshire.

43. Lydekker, R.—1890 'Catalogue of Fossil Reptilia and Amphibia in the British Museum,' iv. p. 217. *Chirosaurus stantonensis* (Morton), Lower Keuper, Storeton, Lymm.

44. Morton, G. H.—1891 'Geology of the Country around Liverpool,' 2nd edition, pp. 106, 299, 300, &c. *Cheirotherium stortonense, C. minus, Rhynchosaurus articeps* (Owen), *Rh. minimus, Rh.* (?) *tumidus, Chelone* (?) *subrotundus, Equisetum keuperinum*, Lower Keuper, Storeton, &c.

45. Gordon, Rev. G.—1892 'Reptiliferous Sandstones of Elgin' ('Trans. Geol. Soc. Edin.').

46. Newton, E. T.—1893 'On some New Reptiles from the Elgin Sandstone' ('Phil. Trans.,' clxxxiv. p. 431, &c.). *Elginia mirabilis, Gordonia Traquairi, G. Huxleyana, G. Duffiana, G. Juddiana, Geikia elginensis, Hyperodapedon Gordoni* (Huxley), Trias, Cuttie's Hillock.

47. Woodward, A. S.—1893 'Some Extinct Sharks and Ganoid Fishes' ('Ann. Mag. Nat. Hist.,' xii. pp. 282-3, pl. x. figs. 1-5). *Ceratodus lævissimus* (Miall), Upper Keuper, Ripple; *Acrodus keuperinus* (M. and S.), Lower Keuper, Coton End; *Phabodus Brodiei* (A. S. W.), Worcestershire, Warwickshire; Upper Keuper, Shrewley.

48. Jeffs, O. W.—1894 'Notes on a series of Fossil Footprints from Storeton, in Cheshire' ('Jour. Liv. Geol. Assoc.,' xiv.). *Rhynchosaurus* (?) *tumidus* (Morton), Lower Keuper, Storeton; *Chirosaurus stortonensis*, Lower Keuper, Storeton; *Rhynchosaurus stortonensis*, Lower Keuper, Storeton.

49. Newton, E. T.—1894 'Reptiles from the Elgin Sandstone—Description of two New Genera' (Phil. Trans., clxxxv. p. 574). *Ornithosuchus Woodwardi* (N.), Trias, Spynie; *Erpetosuchus Granti* (N.), Trias, Loissiemouth.

50. Newton, R. B.—1894 'Note on some Molluscan Remains lately discovered in the English Keuper' ('Journ. of Conch.,' vii. p. 408). *Thracia Brodiei* (R. B. N.), *Pholadomya Richardsi* (R. B. N.), *Nucula keuperina* (R. B. N.), Upper Keuper Sandstone, Shrewley.

51. Beasley, H. C.—1896 'An Attempt to Classify the Footprints in the New Red Sandstone of this district' ('Proc. Liv. Geol. Soc.,' ii. pp. 391-409, pl. i.-iii.). *Rhynchosaurus minimus* (Morton), &c.

52. Beasley, H. C.—1896 'Observations regarding a Footprint from the Upper Keuper Sandstone at Storeton, with a Note on the Probable Structure of the Foot by Professor H. G. Seeley, F.G.S., &c.' ('Trans. Liv. Biol. Soc.,' xi. p. 179, pl. vii). *Chelone* (?) *subrotundus* (Morton), Lower Keuper Sandstone, Storeton.

53. Beasley, H. C.—1898 'Notes on Examples of Footprints, &c., from the Trias in some Provincial Museums' ('Proc. Liv. Geol. Soc.,' viii. pp. 233-4. Footprints, Lower Keuper Sandstone, Storeton, &c.

54. Jones, Professor T. R.—1898 'On some Triassic (?) Estheriæ from the Red Beds or Cimorron Series of Kansas' ('Geol. Mag.,' pp. 291-3, fig. 3). *Estheria minuta* (Alberti).

55. Burckhardt, R.—1900 'On *Hyperodapedon Gordoni*' ('Geol. Mag.,' 4, vii. pp. 486-492 and 529-534, text-fig. 3). *Hyperodapedon Gordoni* (Huxley), Trias, Lossiemouth.

56. Ward, J.—1900 'On the Occurrence of Labyrinthodont Remains in the Keuper Sandstone of Stanton' ('Trans. N. Staffs Field Club,' xxxiv. pl. iv. and v. p. 108). *Capitosaurus stantonensis* (A. S. W.), Lower Keuper, Stanton, near Norbury.

57. Beasley, H. C.—1901 'Notes on the Type Specimen of *Cheirotherium herculis*' (Egerton) ('Proc. Liv. Geol. Soc.,' ix., p. 81, pl. v. and p. 203). *Cheirotherium stortonense* (Morton), Lower Keuper, Storeton.

58. Beasley, H. C.—1901 'On two Footprints from the Lower Keuper and their relation to *Cheirotherium stortonense*' ('Proc. Liv. Geol. Soc.,' ix. p. 238, pl. 15). *Cheirotherium*, Lower Keuper, Storeton.

59. Beasley, H. C.—1901 ('Proc. Liv. Geol. Soc.,' ix. p. 289, pl. 15). *Cheirotherium minus*, Lower Keuper, Storeton.

60. Lomas, J.—1901 'On the Occurrence of Estheria and Plant Remains in the Keuper Marls at Oxton, Birkenhead' ('Proc. Liv. Geol. Soc.,' p. 77, pl. iv.). *Estheria minuta* (Alberti) var. *Brodieana*, Keuper Marl, Oxton, near Birkenhead.

61. Thompson, Beeby.—1902 'Some Trias Sections in South Staffordshire' ('Geol. Mag.,' Dec., iv. ix.). (*Vide* also 'Journ. Northants Nat. Hist. Soc.,' 1902, pp. 21-2). *Rhynchosaurus* and *Cheirotherium*, Upper Keuper, Chillington.

62. Woodward, A. S.—1902 'Footprints from the Keuper of South Staffordshire' ('Geol. Mag.,' pp. 215-7). (*Also* 'Journ. Northants Nat. Hist. Soc.,' 1902, pp. 22-4). *Rhynchosaurus* sp., *Cheirotherium* sp., Upper Keuper, Chillington.

63. Boulenger, G. A.—1903 ('Phil. Trans.,' cxcvi. B, p. 175). *Ornithosuchus Woodwardi* (N.), Trias, Spynie; *Stenometopon Taylori* (Boul.), Trias, Lossiemouth.

64. Boulenger, G. A.—1904 ('Proc. Zool. Soc.'). *Telerpeton elginense* (Boul.), Trias, Lossiemouth.

65. Woodward, A. S.—1904 ('Proc. Zool. Soc.,' ii. p. 170, pl. xi.). *Capitosaurus stantonensis* (A. S. W.), Lower Keuper, Stanton, N. Staffs.

66. Branson, E. B.—1905 'Structure and Relationships of American Labyrinthodontidæ' ('Amer Geol.,' xii. pp. 568-610, figs. 4, 10, and 13).

67. Arber, E. A. N.—1907 'On Triassic Species of the Genera *Zamites* and *Pterophyllum*: types of fronds belonging to the Cycadophyta' ('Trans. Linn.

Soc.,' viii. pt. 7, pp. 109-127, pl. xvii.-xix.). *Zamites grandis* (Arber), Lower Keuper, Bromsgrove.

68. Beasley, H. C.—1907 'The Storeton Find of 1906' ('Proc. Liv. Geol. Soc.,' 1907, pp. 157-171).

69. Wills, L. J.—1907 'On some Fossiliferous Keuper Rocks at Bromsgrove, Worcestershire' ('Geol. Mag.,' December 5, iv. p. 28). Numerous plant, crustacea, fish, and other vertebrate remains. (*Vide* Trias Report, 1907.)

70. Huene, Dr. F. von.—1908 'Eine zusammenstellung über die englische Trias und das alter ihrer Fossilien' ('Centr. für miner. Geol. und Paläont.,' No. 1, pp. 9-17). A summary of the British Keuper Flora and Fauna.

71. Huene, Dr. F. von.—1908 'On Phytosaurian Remains from the Magnesian Conglomerate of Bristol' (*Rileya platyodon*) ('Ann. Mag. Nat. Hist.,' 8th series, i. pp. 228-230, pl. vi.). *Rileya platyodon* (R. and S.), Dolomitic Conglomerate, Bristol.

72. Huene, Dr. F. von.—1908 'On the Age of the Reptile Faunas contained in the Magnesian Conglomerate at Bristol and in the Elgin Sandstone' ('Geol. Mag.,' Dec. 5, v. pp. 99-100).

73. Arber, E. A. N.—1909 'On the Affinities of the Triassic Plant *Yuccites vogesiacus*, Schimper and Mougeot' ('Geol. Mag.,' December 5, vi. pp. 11-14). The name *Zamites grandis* (Arber), first proposed, is rejected in favour of the older *Yuccites vogesiacus*, Schimper et Mougeot, from the Bunter, with which it is regarded as identical, though the *Monocotyledonous* affinity suggested in the latter generic name is not intended to be perpetuated by the retention of the earlier combination.

Preliminary Notice of the Occurrence of Footprints in the Lower Keuper Sandstone of Leicestershire. By A. R. HORWOOD.

Since no authentic specimens of footprints from Leicestershire[1] have, until recently, been forthcoming, it is of some interest to briefly note here the existence of a fairly well-marked example, with all but one digit intact, of *Cheirotherium*, very similar to forms found at Storeton, described by Mr. H. C. Beasley as A 3, and resembling *Cheirotherium herculis* (Eg.). This specimen was found thirty years ago by Mr. J. Large, in excavations for a house at a depth of about 8 feet below the surface, on the Derby Road at Kegworth, in North Leicestershire. It is interesting, moreover, to note by the way that the nearest locality at which these footprints had been obtained hitherto, Weston-on-Trent, Derbyshire, on the north bank of the river Trent, is distant from Kegworth only about six miles. The rareness of their occurrence in this part of the country is, however, sufficient reason for their record here.

The sandstone in which the present example was found (which it is hoped to describe more fully later) is a greenish sandstone passing into 'skerry' of the Lower Keuper intercalated in the red marls, with way-boards or partings of a reddish, flaggy sandstone.

Its existence was made known during excavations for the Derwent Valley Water Board, a scheme by which the boroughs of Leicester, Derby, Nottingham, and Sheffield receive water from the waters of the rivers Derwent and Ashop and higher ground in Yorkshire. These excavations show that nearly opposite the site of the house mentioned a small excavation had been made in the sandstone below the made ground covering the sandstone, giving the appearance in the 6 to 7-feet sewer trench of a deep V-shaped gully, but whether this extended laterally up to the house itself is not known. The sandstone thins out towards

[1] Those recorded in the Report for 1907 are not forthcoming, so that some doubt must be entertained as to their nature, and they are also from the Upper Keuper sandstone.

the river Trent about twenty yards (or rather less) from the spot where the footprint was found, and in the excavations entirely disappeared.

The surface of the greenish (and red) sandstone is here frequently covered with ripple-marks of various sizes, and with considerable variation in the distance between the crest and furrows of each. There are also sun-cracks both along the furrows and preserved separately, having a honeycomb arrangement formed of quadrilateral areas divided by raised ridges, rain-pittings, silt-marks, &c., and pseudo-morphs of salt-crystals (only one specimen of these was found). The footprint referred to was the only organic object found, unless some tracks, probably of invertebrates, are sufficiently definite to include here. The specimen came to light through the finding of two slabs of supposed footprints at the top of the sandstone by the gully mentioned, which were reported to the writer, but turned out to be inorganic casts of some concretionary structure. Within the sandstone similar cavities were filled like a geode with thin films of pink and orange-coloured fibrous gypsum.

Investigation of the Igneous and Associated Rocks of the Glensaul and Lough Nafooey Areas, Co. Galway.—Report of the Committee, consisting of Professor W. W. Watts (*Chairman*), Professor S. H. Reynolds (*Secretary*), Mr. H. B. Maufe, *and* Mr. C. I. Gardiner. (*Drawn up by Mr. C. I. Gardiner and the Secretary.*)

Mr. C. I. Gardiner and the Secretary visited Connemara in April and completed their field work on the Glensaul district, commencing, in addition, to map the Lough Nafooey district.

The Glensaul district is a small one, measuring only about 2 × 1 miles. It is about three miles S.W. of the Southern extremity of the Tourmakeady district, recently described,[1] of which it is clearly a continuation, the type of sedimentary rock met with in the two being practically identical. The general succession is:

III. *?Bala Beds*—conglomerate and sandstone.
These have not been studied.

II. *Llandeilo Beds.*

(5) Calcareous gritty tuff, passing in places into fairly pure limestone, and enclosing bands and patches of limestone breccia and bands of highly fossiliferous limestone, which in some cases has been shattered by earth movement	Thickness doubtful.
(4) Very coarse tuff or breccia mainly composed of felsite fragments	750 feet.
(3) Tuff coarse and fine with occasional patches of calcareous beds	150 feet.
(2) Great felsite sill of Tonaglanna and Greenaun	1,200 feet.
(1) Tuff with some grit	600 feet.

[1] *Quart. Journ. Geol. Soc.*, vol. lxv. 1909, pp. 104–153.

I. *Arenig Beds.*

(4) Coarse grit	150 feet.
(3) Fine grit and tuff associated with black chert, graptolitic shale, and a prominent band of breccia 30 feet thick	Thickness doubtful.
(2) Coarse grit	110 feet.
(1) Coarse conglomerate	About 600 feet seen.

The black shales have yielded the following considerable series of graptolites, which have been kindly determined by Miss G. L. Elles, D.Sc., and indicate the zone of *Didymograptus extensus*. The associated cherts contain radiolaria:—

GRAPTOLITES FROM THE ARENIG BEDS OF GLENSAUL.

Dictyonema, sp.	*Thamnograptus*, sp.
a Dendrograptid.	*Didymograptus extensus*, Hall (common).
Tetragraptus pendens, Elles.	*D. filiformis*, Tullberg.
T. Amii, Lapworth M.S.	*D. fasciculatus*, Nich.
T. quadribrachiatus, Hall.	*D. bifidus*, Hall.
Clonograptus Lapworthi, Rued.	*D. gracilis*, Törnquist.

In the Llandeilo rocks, both limestone and tuff, a large number of generally rather fragmentary fossils was found, which are being determined by Mr. F. R. Cowper Reed.

The crystalline igneous rocks, all of which we believe to be intrusive, are by no means so varied as in the Tournakeady district, and are practically limited to one broad band of felsite, which is noteworthy from the fact that it almost everywhere contains pyroxene.

The district is much faulted, large faults bound it on the E. and W., a somewhat complicated system of faults approximately parallel to these bounding faults intersects it, and there are other dislocations of importance.

Composition and Origin of the Crystalline Rocks of Anglesey.—Fourth Report of the Committee, consisting of Mr. A. HARKER (*Chairman*), Mr. E. GREENLY (*Secretary*), Dr. C. A. MATLEY, *and* Professor K. J. P. ORTON.

THE Committee record with great regret the loss they have sustained in the death of Mr. J. Lomas, which occurred in the prosecution of geological research in Algeria.

The work of the year has included the completion of the series of analyses of rocks of the hornfels type in Central Anglesey; and now the pillowy diabase lavas with jaspers and other associated rocks (perhaps the most important in the island; of far-reaching importance, indeed, among ancient rocks beyond its limits) are being proceeded with. A series, also, of limestones and mudstones from the Carboniferous limestone and Old Red rocks have been analysed, which were collected during the survey of the Carboniferous limestone area in 1907 and upon which chemical information was greatly needed. Lastly, a gneissose marble, containing pseudomorphs after Forsterite, has been analysed.

All the analyses are by Mr. John Owen Hughes, B.Sc., who continues to devote to this work whatever time is allowed by his duties as Demonstrator in Chemistry in the University College of North Wales.

No. 557A. *Hornfels.*

7 *S.E. Cromlech. Bodafon Mountain.*

	I.		II.
SiO_2	58·52		58·27
Al_2O_3	23·40		23·45
Fe_2O_3	3·02		3·18
FeO	2·30		2·22
MnO	—		—
CaO		0·11	
MgO		1·52	
K_2O	6·58		6·61
Na_2O	0·22		0·35
H_2O (at 110° C.)	0·45		0·46
H_2O (above 110°)	3·55		3·51
	99·67		99·68

This rock completes the series from the hornfels associated with the granite. The high alkali percentage in some of these suggested doubts as to whether they could be of sedimentary origin. The alkalies are, however, quite as high in this rock, and of its sedimentary origin there can be no doubt, the evidence in the field and under the microscope being decisive. It is from the beds which pass under the great quartzite of Bodafon Mountain, and was obtained in a small quarry which was made, with most fortunate results, right through the junction, in the spring of 1908.

No. 107A. *Dolerite.*

22 *S.W. Boss S.W. of Bryn Llwyd.*

	I.	II.	III.	IV.
SiO_2	47·43	47·47		
TiO_2	trace			
Al_2O_3	17·58	17·49		
Fe_2O_3	2·08	2·01		
FeO	7·45	7·42		
MnO	trace			
CaO	10·92	11·01		
MgO	6·71	6·73		
K_2O	trace			
Na_2O	3·89	3·97	3·50	4·23
H_2O (at 110°)	0·25	0·22		
H_2O (above 110°)	2·65	2·68		
CO_2	0·53	0·56		
	99·49	99·56		

No. 107A. This is the pillow diabase lava of the Newborough district, from the best sections, where it is quite undeformed and unaltered.

No. 518A. *Jasper.*

22 *S.W. Cerig Mawr. In Ellipsoidal Diabase.*

	I.	II.
SiO_2	88·01	88·13
Al_2O_3	1·36	1·25
Fe_2O_3	10·68	10·82
Alkalies	None	—
	100·05	100·20

This is the jasper which occurs in the interstices of the pillowy diabase. It will be seen that the analysis is quite unlike that of any felsite or rhyolite, unless such a rock had been altered by introduction of silica and iron, and of such a phenomenon there is no evidence whatever on the ground. The relations, moreover, of the jasper to the diabase are quite inconsistent with such a view.

Llanddwyn, near 312A.

Dolomitic Limestone.

Percentage $MnO = \cdot 01$
$\therefore$,, $MnCO_3 = \cdot 016$

This is to supplement an analysis made in a former year of a limestone associated with the pillowy lavas and jaspers. Jaspers occur in these limestones, as well as in the lavas. They frequently have a delicate rose colour, and this, it will be seen, is due to substitution in the carbonate of a small percentage of rhodochrosite.

Nos. 548 and 549 have been selected as extreme types of the limestones of the Carboniferous series, some of which are thick-bedded, light coloured, clean, and crystaline; the others thin-bedded, dark coloured, earthy, and compact.

No. 548A. *White Limestone. Carboniferous.*

Benllech Cove.

	I.	II
Residues insoluble in HCl	0·32	0·41
$Al_2O_3 + Fe_2O_3$	0·17	0·19
CaO	55·43	55·37
MgO	—	—
CO_2	44·16	44·19
	100·08	100·16
Percentage $CaCO_3$	98·98	98·87

Very white and crystalline. Its purity is remarkable. Corals are often abundant in the limestone of this type.

No. 549A. *Black Limestone. Carboniferous.*
Benllech Sand.

	I.	II.
Residues insoluble in HCl	22·02	21·66
$Al_2O_3 + Fe_2O_3$	0·24	0·49
CaO	41·57	41·61
MgO	1·07	1·16
CO_2	33·83	33·91
	98·73	98·83
Undetermined =	1·27	1·17
Percentage $CaCO_3$ =	74·23	74·30

The insoluble portion has the following composition:—

SiO_2	91·00	90·23
$Al_2O_3 + Fe_2O_3$	8·95	9·28
	99·95	99·51

The undetermined part consists of free carbon and some volatile sulphides. During the grinding process the smell of H_2S or some organic sulphide was detected, and lead acetate paper was blackened when held near the freshly-ground rock. An attempt was made to dry distil the rock and condense the vapours evolved, and this was partly successful. When the powdered rock was strongly heated fumes were evolved having an offensive odour resembling that of petroleum as well as H_2S, and which were condensed to a pale yellow oil; as, however, only about three drops were collected it could not be further examined.

Further examination of this rock would be of great interest.

This rock is thin-bedded, compact, and very dark. Corals are rare, and indeed fossils generally less abundant than in the other type, except in certain seams in which are large numbers of *Productus giganteus*.

Nos. 546A, 547A, have been examined on account of the dolomitic appearance that certain beds assume in the neighbourhood of masses of coral.

No. 546A. *Grey Limestone. Carboniferous.*

Penrhyn y Gell. Traeth Bychan.

	I.	II.
Residues insoluble in HCl	7·93	7·99
$Al_2O_3 + Fe_2O_3$	0·62	0·58
CaO	50·49	50·53
MgO	0·69	0·51
CO_2	40·42	40·35
	100·15	99·96
Percentage $CaCO_3$ =	90·16	90·23

This is a massive, lightish grey limestone, of a type that makes up a great part of the Carboniferous series. The percentage of insoluble residues is higher than might have been expected from the appearance of the rock.

No. 547A.

From same bed as 546A, *but close to a coral.*

	I.	II.
Residues insoluble in HCl	0·24	0·18
Al_2O_3	0·63	0·69
Fe_2O_3	1·45	1·34
FeO	5·58	5·63
CaO	30·25	30·36
MgO	16·22	16·19
CO_2	45·75	45·69
	100·12	100·08
Percentage $FeCO_3$ =	8·99	9·07
„ $CaCO_3$ =	54·01	54·19
„ $MgCO_3$ =	34·06	33·99

It will be seen that in the neighbourhood of the coral, iron as well as magnesium replaces calcium in the carbonate, and that the insoluble residues sink from nearly 8 to less than ·5 per cent.

No. 544A.

Mass of Dolomite in Carboniferous Conglomerate. Lligwy Bay.

	I.	II.
Residues insoluble in HCl	1·02	1·21
$Al_2O_3 + Fe_2O_3$	17·16	17·07
CaO	29·67	29·88
MgO	10·02	9·95
CO_2	42·28	42·22
	100·15	100·33
Percentage $CaCO_3$	52·98	53·35
,, $MgCO_3$	21·04	20·89

This is from some curious, irregular masses that occur in very coarse conglomerates at the base of the Carboniferous series.

No. 511A. *Red Muddy Sandstone.*

7 N.E. Traeth yr Ora.

	I.	II.
Residues insoluble in HCl	84·79	85·03
$Al_2O_3 + Fe_2O_3$	8·31	8·18
CaO	1·17	1·28
MgO	2·10	2·06
CO_2	3·58	3·52
	99·95	100·07
Percentage $CaCO_3$	2·08	2·28
,, $MgCO_3$	4·41	4·33

This is perhaps the most prevalent type of rock in the Old Red series. In it occur many beds of cornstone.

No. 478A. *Forsterite Limestone.*

3 *S.E.* 500 to 800 *feet N.E. of Rhosmynach. At Contour.*

	I.	II.
Residues insoluble in HCl	37·77	37·44
Al_2O_3	2·53	2·35
Fe_2O_3	3·03	3·10
CaO	29·05	29·37
MgO	2·18	2·27
CO_2	25·64	25·56
	100·20	100·09
Percentage $CaCO_3$	51·87	52·44

This rock is one of a group of limestones that occur in a highly crystalline gneissose complex in the N.E. of Anglesey. They are all rich in crystalline silicates (to which is due the high percentage of insoluble residues), and among these are pseudomorphs that are almost certainly after Forsterite. An analysis of the insoluble residues will probably reveal much more magnesium than that which still remains as a carbonate.

NOTE.—The analyses completed up to date may be summarised as follows:—A series from the Hornfels group, to which it will not be

necessary to add any more, though the granite itself and the basic gneiss should be analysed if possible. Partial analyses of a number of the dykes, to which a few more should be added in order to compare dykes of different groups. A series from the Carboniferous limestone, which may be regarded as sufficient. The principal rocks of the Serpentine-Gabbro complex have now been done, but tremolitic and other exceptional rocks of that complex should be added. The important groups of the jaspers and pillowy diabases are now nearly finished. But of the schists into which they are believed to pass only one or two have been analysed, and as difference of opinion still exists concerning the origin of some of these, and as they are widespread types, the question is an important one. This, indeed, is the most important research yet remaining from the chemical point of view, and Mr. Hughes is preparing to go on with it. Even when that and some miscellaneous rocks of exceptional interest have been dealt with, large groups, particularly in the Holyhead and northern region of the island, will still remain, and it may not be possible to deal with these.

The Secretary hopes to complete the map in about a year, and detailed written descriptions in perhaps eighteen months after that, and while this work is proceeding Mr. Hughes intends to go on with the analyses as indicated.

There is scarcely any wear and tear of apparatus, the average annual expenditure is under 1*l.* A small grant to cover this for, say, the three years remaining is asked for.

The Committee therefore ask to be reappointed, and to replace the late Mr. Lomas it is proposed to appoint Dr. John Horne, F.R.S., the Assistant Director of the Geological Survey of Scotland. Dr. Horne paid an (official) visit of a week to the Secretary last autumn, has taken unremitting interest in the work since then, and is willing to serve on this Committee.

Erratic Blocks of the British Isles.—Report of the Committee, consisting of Mr. R. H. Tiddeman (*Chairman*), Dr. A. R. Dwerryhouse (*Secretary*), Dr. T. G. Bonney, Mr. F. M. Burton, Mr. F. W. Harmer, Rev. S. N. Harrison, Dr. J. Horne, Professor W. J. Sollas, *and* Messrs. J. W. Stather *and* W. T. Tucker.

Reported by Mr. A. C. Dalton.

From the neighbourhood of Scunthorpe, in Lincolnshire :—

1 specimen of	Elæolite Syenite, Norway.
4 specimens	Andesite from Lake District.
1 specimen	Andesitic Ash, Lake District.
1 ,,	Andesitic Breccia, Lake District.
1 ,,	Fine-grained grit (Silurian), South of Scotland.
1 ,,	Porphyrite, Cheviot District.
1 ,,	Hard Chalk, Yorkshire.

Also the following rocks of unknown derivation :—

1 Carboniferous limestone.
1 ,, sandstone.
1 Millstone grit.
1 Diorite.
1 Fine-grained granite.
4 Dolerite.
8 Quartzite (probably from Trias).
5 Sandstone (from secondary rocks).
2 Limestone (from secondary rocks).
1 Micaceous grit.
1 Coarse grit.
1 Porphyrite.
4 Mica schist.
1 Mica-chlorite-schist.
1 Hornblende schist.
1 Hornblende granite.
1 Quartzose breccia (probably fault-rock).
2 Chert.
1 Chert with Oolitic structure.
1 Vein quartz.
1 Felspathic grit with blue quartz.

Reported by Rev. E. ADRIAN WOODRUFFE-PEACOCK, *F.L.S.*, *F.G.S.*

A specimen of a coarse grit found in the neighbourhood of Brigg, in Lincolnshire, which, in the opinion of several members of the Geological Survey, strongly resembles the grits of the Highland Border.

Reported by Mrs. ERNEST JONES, *Harwood Dale, Kendal.*

A large boulder of Shap granite exposed during the excavations for the foundation of a house on the outskirts of Kendal.

The following boulders found in Northumberland and Durham are reported through the Boulders Committee of the University of Durham Philosophical Society.

(i.) *Reported by* Dr. J. A. SMYTHE.

(*a*) From Eachwick Kaims, Eachwick, three miles west of Ponteland, Northumberland :—

Threlkeld granite. Volcanic series of Borrowdale. Greywacke. Cheviot porphyrite. Granite. Whin Sill. Carboniferous limestone. Basalt.

(*b*) From Kirkley Kaims, Kirkley Hall, three miles north of Ponteland, Northumberland :—

Volcanic series of Borrowdale. Greywacke. Various granites. Several porphyrites. Chert. *Saccamina* limestone. Amygdaloidal lava. Carboniferous limestone. Basalt.

(*c*) From Dewley Hill Kaim, near Walbottle, Northumberland :—

Armboth Dyke. Volcanic series of Borrowdale. Greywacke. Cheviot porphyrites. Quartz pebbles. Several granites. Carboniferous limestone. Basalt.

(*d*) From pebble bed, Duddo Burn, near Stannington, Northumberland :—

Cheviot porphyrite. Greywacke. Chert. Coarse granite.

(*e*) From pebble bed, Shilvington Slack, near Whalton, Northumberland :—

Cheviot granite. Basalt. Greywacke.

(*f*) From boulder clay, Braid Hill, Callerton, Northumberland :—

Threlkeld granite. Decomposed Criffel granite.

(*g*) From boulder clay, How Burn, near Foulmartlaw, near Bolam, Northumberland :—

Coarse granite with porphyritic felspar.

(*h*) From boulder clay, River Blyth, near Thorneyford, three miles north of Ponteland, Northumberland :—

Criffel granite.

(*i*) From boulder clay, Gurry's Point, Monkseaton, Northumberland :—

Volcanic series of Borrowdale. Granite. Cheviot porphyrite.

(*j*) From boulder clay, Coast near Brier Dene Burn, Monkseaton, Northumberland :—

Cheviot porphyrite. Basalt. Diorite. Several granites.

(*k*) From boulder clay, Kenton Quarry, near Newcastle :—

Threlkeld granite. Armboth Dyke. Volcanic series of Borrowdale. Coarse grey and red granite. Eurite (Cheviots ?). Purple Cheviot porphyrite.

(*l*) From boulder clay, Brunton Quarry, near Newcastle :—

Volcanic series of Borrowdale. Greywacke. Cheviot granite.

(ii.) *Reported by* Dr. Woolacott.

(*a*) From Grindon Kaim, near Sunderland :—

Cheviot granite. Red granite. Borrowdale volcanic series. Quartz pebbles. Greywacke. Felsite. Carboniferous limestone. Felspathic grit. Ironstone. Coal. Quartz porphyry. Cheviot porphyrite. Whin Sill. Basalt. Numerous pieces of Magnesian limestone—some of the cannon-ball and other concretionary types.

(*b*) From boulder clay, Whitley Bay, Northumberland :—

Volcanic series of Borrowdale. Cheviot porphyrite.

(*c*) From boulder clay, quarry near Horden, Durham :—

Volcanic series of Borrowdale.

(*d*) From raised beach, Cleadon, near Sunderland :—

Piece of chalk. Black flint with chalk attached. Several flints.

(*c*) From boulder clay, The Flats, North Shields :—

Cheviot porphyrite.

(*f*) From boulder clay, Hendon Banks, Sunderland :—

Cheviot porphyrite.

(*g*) Boulders of Volcanic series of Borrowdale reported from east of Hetton-le-Hole, Consett and Wingate Old Quarry, Durham.

(*h*) From boulder clay, Kenton Quarry, near Newcastle :—

Besides those reported by Dr. Smythe: dark fresh porphyrite (Cheviots ? 5 cubic feet in volume). Grey granite (Criffel ?). Basalt. Shale with cone-in-cone structure. Red conglomerate.

(*i*) From boulder clay, Claxheugh, Sunderland :—

Cheviot porphyrite. Cheviot felsite. Basalt. Carboniferous limestone.

(iii.) *Reported by* Mr. E. Merrick *and* Dr. Woolacott.

(*a*) From boulder clay, Nightingale's Brick Works, Forest Hall, near Newcastle :—

Rhyolyte. Cheviot porphyrite. Greywacke. Diabase. Garnetiferous mica schist. Carboniferous limestone.

(*b*) From Tyne Quarry, Walker, near Newcastle :—

Volcanic series of Borrowdale. Threlkeld granite. Quartz felsite. Cheviot porphyrite. Volcanic ash. Schist. Red and grey granites. Carboniferous limestone (5 cubic feet in volume).

(*c*) From black stony clay, Standard Brick Works, Heaton, Newcastle-upon-Tyne :—

Piece of chalk. Amygdaloidal tuff.

(*d*) From boulder clay, Walker Clay Pit, near Newcastle :—

Cheviot porphyrite. Tuff.

(*e*) From black clay, Walker Clay Pit, near Newcastle :—

Striated boulder of chalk.

(*f*) From Bird's Nest Quarry, Walker, near Newcastle :—

Dark fresh porphyrite (Cheviots).

(*g*) From boulder clay, Butcher Hill, near Matfen, Northumberland :—

Cheviot porphyrite. Granite.

(*h*) From boulder clay, Brickyard, near Marden Tower, Whitley, Northumberland :—

Cheviot amygdaloidal andesite. Carboniferous limestone coral. Magnesian limestone.

(*i*) From boulder clay, Whitley Links, Whitley, Northumberland :—

Cheviot porphyrite.

(*j*) From yellow clay, Robson's Sand Pit, Heaton, Newcastle :—

Quartz felsite. Cheviot porphyrite. Basalt.

(*k*) From boulder clay, Brick's Limited, Forest Hall, near Newcastle :—

Volcanic series of Borrowdale. Basalt. Carboniferous limestone. Gabbro (Carrock Fell ? 1 cubic foot in volume).

(*l*) From boulder clay, Benton Loop, North-Eastern Railway, near Newcastle :—

Volcanic series of Borrowdale.

(*m*) From clay, Leam Head, Springwell, near Gateshead :—

Threlkeld granite (two boulders, one of them 1 cubic foot in volume). Whin Sill. Volcanic series of Borrowdale.

(*n*) From clay, Moss Heaps, Wrekenton, near Gateshead :—

Granite. Greywacke.

(iv.) *Reported by* Rev. W. J. Wingate.

Volcanic ash of volcanic series of Borrowdale found near Crook, and Threlkeld granite found at Bishop Auckland.

(v.) *Reported by* Mr. A. Bell.

Volcanic series of Borrowdale at St. Helens, near Bishop Auckland.

Boulders Committee.

Report No. 3. *March* 1909.

The following boulders and pebbles have been collected and determined by members of this Committee since the last report was issued :—

(I.) From boulder clay, Keaton, near Newcastle. Collected by R. C. Burton, G. Weyman, and the members of Armstrong College Geological Surveying Class :—

Dark fresh porphyrite (Cheviots ? 5 cubic feet). Threlkeld granite (½ cubic foot). Several pieces of volcanic series of Borrowdale. Cheviot granite. Grey granite (Criffel ?). Basalt (several). Shale with cone-in-cone structure (several). Carboniferous limestone (numerous). Red conglomerate. Clay ironstone. Septarian nodule. Sandstone.

(II.) From Grindon Kaim, near Sunderland. Collected by Dr. Woolacott.

Pebbles, mostly small, with one or two exceptions all less than ½ cubic foot.
Cheviot granite. Red granite. Borrowdale volcanic series (numerous). Magnesian limestone (very numerous)—some specimens of the cannon-ball and other concretionary types. Quartz pebbles. Greywacke (several). Felsite. Carboniferous limestone. Felspathic grit. Coal. Shale. Sandstone. Quartz porphyry. Purple porphyrite (Cheviots). Ironstone. Whin Sill. Basalt.
Some of the stones were scratched. An incipient cementation occurs in places.

(III.) From boulder clay, small quarry behind Claxheugh, near Sunderland. Collected by Dr. Smythe and Dr. Woolacott.

Cheviot porphyrite. Cheviot felsite. Basalt. Carboniferous limestone.

(IV.) Tyne Quarry, Walker, near Newcastle :—

(*a*) From 'rag' or 'mixture clay.' Volcanic series of Borrowdale. Basalt. Decomposed red granite. Sandstone. Carboniferous limestone (5 cubic feet).
(*b*) Lying loose. Volcanic ash. Schist. Volcanic series of Borrowdale (5,[1] one 1 cubic foot). Greywacke (2). Granite (red and grey). Threlkeld granite (3). Quartz felsite (2). Cheviot porphyrite. Granite (Criffel ?) (2). Red grit.

[1] The numbers placed after some of the specimens refer to number of that rock noted. The size of the specimen is given wherever it is noteworthy.

(V.) Bird's Nest Quarry, Walker, near Newcastle :—

Dark fresh porphyrite. (Cheviot, ½ cubic foot.)

(VI.) Brick's Limited, Forest Hall, near Newcastle :—

Volcanic series of Borrowdale. Basalt. Carboniferous limestone (numerous). Gabbro (Carrock Fell ?, 1 cubic foot).

(VII.) Benton Loop, North-Eastern Railway, near Newcastle :—

Volcanic series of Borrowdale.

(VIII.) Leam Head, Springwell, near Gateshead :—

Threlkeld granite (2, one 1 cubic foot). Whin Sill. Volcanic series of Borrowdale (2).

(IX.) Moss Heaps, Wrekenton, near Gateshead :—

Granite. Greywacke.

(IV. to IX.) collected by E. MERRICK and Dr. WOOLACOTT.

(X.) Boulder clay. Nightingale's Brick Works, Forest Hall, near Newcastle :—

Garnetiferous mica schist.

(XI.) 'Black clay.' Walker Clay Pit, near Newcastle.

Striated boulder of chalk.

(X. and XI.) collected by E. MERRICK.

Striations on the rock surface have been observed at Brick's Limited, Forest Hall, near Newcastle. Direction, N.W.–S.E.

The following notes are contributed by Mr. A. R. HORWOOD, of the Leicester Museum :—

Distribution of Erratic Blocks in the Drift of Leicestershire.

These notes are supplementary to those previously published by Messrs. PLANT and others, recorded in earlier reports upon the Erratic Blocks, and to the summary compiled by Mr. C. FOX-STRANGWAYS, F.G.S., in 'Geology of the Country around Leicester,' 1903, pp. 59–60 ('Mem. Geol. Surv. Explanation of Sheet 156').

The notes are best arranged according to localities, and these have been grouped together in the drainage areas to which they respectively belong. For it is clear that the present valleys are simply preglacial valleys which have been traversed by glaciers, leaving their accumulations of boulder clays, sands and gravels in these same valleys, and also in plateau form upon the hills. The source of the boulders, either from the north-west or north-east, is sufficiently clear to those conversant with the different boulder clays and the characteristic erratics of each.

A.—Valley of the River Soar.

1. *North of Leicester.*

Leicester (*Essex Road*).—A block of weathered Mount Sorrel granite, 4 ft. 6 in. by 2 ft. 6 in. by 1 ft. 6 in., somewhat angular and roughly pentagonal, lying parallel with the road, occurs here. It has no doubt been

brought to its present position by human agency from adjacent beds of drift.

Leicester (*Vass's Brickyard*).—A small block of Mount Sorrel granite, 15 in. by 8 in. by 6 in., has a rounded surface, and there are other smaller blocks, chiefly of granite, but also of slate, probably from Swithland, in proximity, with quartzite pebbles.

Leicester (*County Brick Works*).—A large roughly trigonal or three-sided boulder of Mount Sorrel granite, has a facetted contour. It is much pitted and fretted. It contains patches of darker colour, which may be 'segregation masses.' It measures 38 in. by 38 in. by 34 in. The edges are more or less rounded.

Leicester (between Leicester and Thurmaston), *Star Brick Works*.—Here there are many boulders, varying in size from cubes of 2 ft. to 3 ft., and various types of sandstones and quartzites. Several slabs of sandstone, measuring *circ.* 1 ft. by 8 in. by 6 in., are quite flat upon one side, rounded or roughly quadrangular on the other. Small angular granite boulders occur in the river-gravels at this point. Many of the small pebbles and boulders in the latter are normally horizontally bedded, but others occur *in situ*, like Bunter pebbles—which many of them undoubtedly actually are—with the longer axis vertical. It is difficult to account for this phenomenon except by assuming the existence of somewhat turbulent currents at certain points, or eddies, accompanied by pounding and rapid deposition of sand and gravel, which would tend to arrange the larger blocks in a manner not consistent with the normal relation between the specific gravity of the boulders and the surrounding matrix.

Leicester (Belgrave Brick Co.).—In drift overlying red marl a small boulder of Mount Sorrel granite and many small quartzites, much resembling the Hartshill quartzites, and milky white flints, occur.

Leicester (Barrow's Brick Pit, West of the Midland Railway).—Countless rounded quartzite pebbles, some like the liver-coloured variety, but varying greatly in colour and texture, occur, and rocks of northern origin are intermixed with others, such as granite, millstone grit, Coal-measure sandstone, &c., of local or Derbyshire origin. Flints are not so plentiful as at the last locality, immediately south. One mass of granite (15 in. by 8 in. by 6 in.) has a curiously rectangular shape, with a regularly pitted and polished surface, soapy to the touch. Millstone grit is pretty abundant, and some dark rocks and a banded slate, probably from Charnwood Forest. The size of the rounded quartzite pebbles, many of which are derived from the Bunter, is remarkably uniform, varying from 3 in. or 4 in. to 6 in., some few more, some less. The shape, too, is characteristic, and in their outline one can see an originally quadrangular shape, or occasionally a much more irregular original contour. All degrees of smoothness and angularity are represented, and the origin of these pebbles must be extremely heterogeneous, for when split open they betray very diverse sources, the colour, texture, hardness, composition of the quartzites being very variable, every gradation between a true quartzite and a coarse or fine sandstone or grit existing.

Thurmaston Brick Co.'s Pit.—Several large blocks of Mount Sorrel granite, one very large block of Coal-measure sandstone, Rhaetic and Lias limestone, and bolite, varying from cubes of 2 ft. to 3 ft., are found here, indicating a mixed origin of the drift beds above the Quartzose sand.

2. *South of Leicester.*

Knighton Junction Brick Co.—Several large blocks of granite, probably from Mount Sorrel, occur here, one with dark patches similar to those seen at the County Brickworks, and varying from 2 ft. by 2 ft. by 1 ft. 6 in. to cubes of larger size. Small quartzite pebbles are again abundant. One large block of granite is roughly hexagonal, and in the direction of the longer axis is 35 in., the greatest breadth 28 in., and the height 1 ft. 3 in. The sides are in parts flat and worn, smooth and polished. In others a kind of 'skin' covers the surface. Some thirteen of small size lying near are smooth and polished, with the same skin-like covering, and one is square. In some cases the original angular corners have been worn smooth.

Leicester, Saffron Lane (*Underwood's Pit*).—Mount Sorrel granite boulders from 3 ft. cubes to smaller sizes occur here, many being 1 cubic foot. Slabs of Swithland slate are also to be found. Some very large quartzites are to be seen uniformly distributed. The following examples of granite measured were 35 in., 38 in. by 28 in. by 16 in., 37 in. by 29 in. by 18 in., with rounded edges, a smoothed and polished surface, in parts with felsitic veins.

Aylestone (south of Middleton Street).—A large roughly rectangular boulder, with angular corners and smooth sides, of Mount Sorrel granite; is 39 in. by 35 in. by 26 in.

Biggs' Sand Pit.—A large boulder, whose longer diagonal lay N. by S., measured 52 in. by 44 in. by 36 in. About 1 ft. of the boulder was embedded in the underlying, rather soft, quartzose sand, and around the base the matrix was puddled, due to drainage from its area collecting at the base, and causing the boulder to gradually settle lower down into the sand. The upper portion lay in reddish boulder clay.

Blaby (Hafford's Brickyard).—A large boulder of Mount Sorrel granite, 39 in. by 31 in. by 12 in., occurs here, with many smaller ones of different age; many of them are very rounded and smooth and polished. Several rounded blocks of millstone grit, some Coal-measure, sandstone, skerry, and Keuper sandstone also occur. The quartzite pebbles are very large.

B.—Tributaries draining ground east of the River Soar, running into the Soar.

Thurnby (Sand-pit, north of Houghton Road).—Here a few granite boulders and quartzites may be seen in hollows in the glacial sands and gravels.

A large boulder of granite, 50 in. by 31 in. by 1 ft., lies at the side of the well in the village. It is flat-topped, and though placed where it now stands by human agency it doubtless comes from glacial beds close by.

Ingarsby (near Butt's Farm).—Several blocks of Mount Sorrel granite lie about—*e.g.*, one angular block 18 in. by 18 in., one rounded block 18 in. by 18 in. *circ.*, one rounded block 3 ft. by 2 ft. Between this point and Houghton there is a large slab of angular, roughly quadrangular marlstone, near a pit in glacial sands and gravels, 39 in. by 19 in. by 14 in.

Between Withcote and Launde.—By the stream-side near Launde a large boulder of tufa, 54 in. by 49 in. by 22 in., lies on rising ground, with slightly rounded edges.

Investigation of the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, and at various localities in the East Riding of Yorkshire.—Report of the Committee, consisting of Mr. G. W. LAMPLUGH (*Chairman*), Mr. J. W. STATHER (*Secretary*), Dr. TEMPEST ANDERSON, Professor J. W. CARR, Mr. W. LOWER CARTER, Dr. A. R. DWERRYHOUSE, Mr. F. W. HARMER, Mr. J. H. HOWARTH, Rev. W. JOHNSON, Professor P. F. KENDALL, *and* Messrs. G. W. B. MACTURK, E. T. NEWTON, CLEMENTS REID, *and* THOMAS SHEPPARD. (*Drawn up by the Secretary.*)

IN our report for 1907, presented at the Leicester meeting of the Association, it was mentioned that difficulty had been found in obtaining permission to excavate on a site in East Yorkshire, on which it had been intended to carry on the work. This difficulty proving insuperable, the committee decided to carry further the investigation already begun upon the Bielsbeck site, as described in the report above mentioned.

The extent of the fossiliferous deposit at this site had already been partly determined by boring tools, and it was hoped that by sinking small pits in places not previously explored in this manner, further results of interest might be obtained. This has now been done so far as the funds still remaining in our hands would allow, and a further collection of bones and other fossils has been secured, without, however, materially adding to the previous lists. It is not therefore proposed to apply for a further grant, and it remains only to describe the work of the last season.

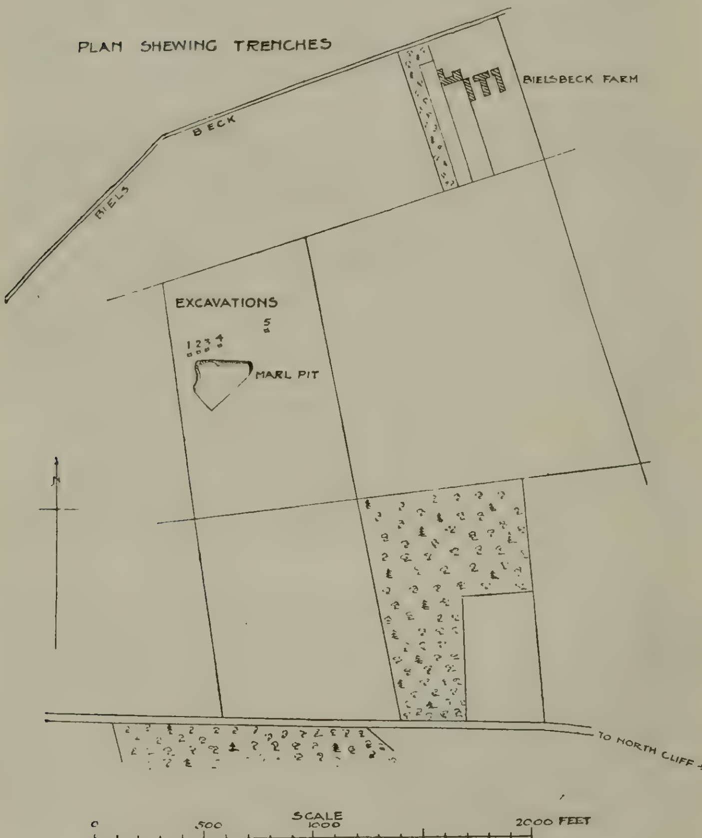
The position and previous history of the Bielsbeck deposit was described in our report for 1907 and need not be repeated. The work done last autumn (1908) was the sinking of a series of trenches or pits, each having a diameter of from 8 to 10 feet, as shown on the plan and sections, pp. 178 and 179:—

It will be seen from the diagrams that in pits Nos. 1 and 5 the unfossiliferous gravel rested directly on the Keuper Marl, but that in the other pits a wedge-shaped mass of the fossiliferous black marl intervened between them. From this material, in pits Nos. 2, 3, and 4, were obtained numerous bones, mostly more or less imperfect. These bones, which in the aggregate weighed about 1 cwt., have been preserved, and the determinable specimens have been submitted to Mr. E. T. Newton, F.R.S., who reports that two species of animals alone appear to be represented, viz., *Elephas primigenius* and *Bison priscus*. Of the former animal the remains included:—

BONES FROM BIELSBECK, 1909.

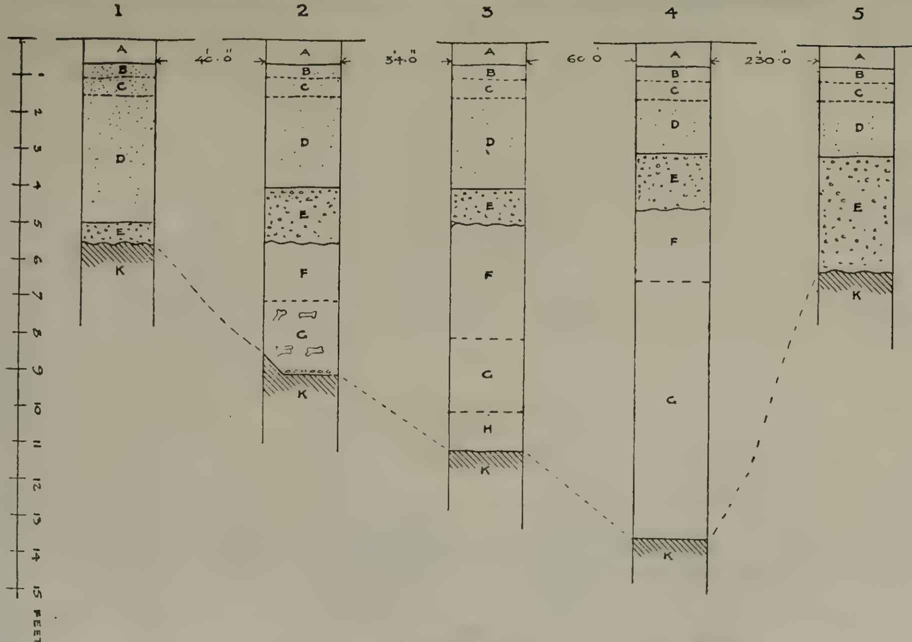
1	*Elephas primigenius?*	5 pieces of a tusk.
2	" "	distal end of humerus.
3, 4, 5	" "	shaft of humerus (4 pieces).
6	" "	ditto.
7	" "	piece of pelvis.
8	" "	distal end of fibula.

Bielsbeck, East Yorks. Excavations, 1908.



Bielsbeck, East Yorks. Excavations 1908.

Sections of the trenches (numbers refer to the numbers of the trenches on the plan).



A—Sandy surface soil. B—Whitish sand. C—Brownish sand. D—Rusty-coloured sand. E—Sandy chalky gravel. F—Greenish marl. G—Black marl, with bones. H—Compact black marl, with bones. K—Keuper Marl.

9	*Elephas primigenius ?*		left cuboid (hind foot).
10	" "		left cuneiform of hind foot.
11	" "		rib.
12	" "	?	rib.

Of *Bison priscus* were found:—

13	*Bison priscus*		horn core.
14	" "		base of skull.
15	" "		piece of skull.
16	" "		last lower molar.
17	" "		lower molar.
18			
19			
20	" "		portions of lower jaws.
21			
22	" "		condyle of skull.
23			
24			
25			
26	" "		vertebræ.
27			
28			
29			
30			very large tibia (distal end).
31	" "		
32			scapula (pieces).
33	" "		
34			pieces of femur.
35	" "		
36	" "		piece of distal end of tibia.
37			distal condyles of femur.
38	" "		
39	" "		fragments of tibia.
40			
41			
42			
43			
44	" "		fragments of limb bones.
45			
46			
47			
48	" "		piece of pelvis ?
49	" "		piece of skull ?
50	" "	?	rib.
51	" "	?	rib.
52	" "	? ?	fragments.
53	" "	?	patella.
54	" "	?	rib.
55	" "	?	neural arch.

The results obtained were thus in full agreement with those of the earlier investigators and of our own work of 1906, and the general conclusions as to the origin and character of the deposit stated in our report of 1907 are confirmed.

The Committee desire again to record their thanks to W. H. Fox, Esq., for permission to excavate; to the tenant, Mr. Howes; to Mr. W. H. Crofts; and to Mr. T. Stainforth for his services in superintending the work and dealing with the material collected.

The Committee do not ask for reappointment.

The Excavation of Critical Sections in the Palæzoic Rocks of Wales and the West of England.—Report of the Committee, consisting of Professor C. LAPWORTH (*Chairman*), Mr. G. W. FEARNSIDES (*Secretary*), Dr. J. E. MARR, Professor W. W. WATTS, *and* Mr. G. W. WILLIAMS.

On some further Excavations among the Cambrian Rocks of Comley, Shropshire, 1908, by E. S. COBBOLD, *F.G.S.*

THE excavations made during 1907 in the Cambrian rocks of Comley, Shropshire, were reported upon to the Dublin meeting of the British Association. These excavations were unavoidably interrupted early in the autumn of that year, and resumed in the spring and summer of 1908.

The additional excavations form the subject of this second communication.

The positions of the excavations of 1907 were shown on a sketch-map (reprinted below), and numbered 1 to 19; those of 1908, which were confined to Dairy Hill, the Shoot Rough Road, and one spot near the Comley Quarry, can be localised thereon from the notes appended.

Dairy Hill Excavations.

It had been ascertained by Excavation No. 3, 1907, that the lane round the north end of Dairy Hill was cut through a domical covering of the conglomerate of the Quarry Ridge Grits to the Olenellus Limestone and Lower Comley Sandstone below; also by Excavation No. 10 that rock similar to the Quarry Ridge Grits occurs at the top of Dairy Hill; and by Excavation No. 12, in the disused quarry near the south fence of the Dairy Hill field, that rocks very similar to the Lower Comley Sandstone occur there.

It was a natural inference that the place of the Olenellus Limestone lay between these two last-mentioned excavations; but it seemed advisable first to ascertain more exactly the nature of the junction between the two sets of beds in the Dairy Hill Lane, and to seek an explanation of the absence of the Black, Grey, and French Grey Limestones which occur between them in the Quarry Ridge (see Sections Nos. 1 and 2 of the previous report).

With this view Excavation No. 3 in the south bank of the lane was enlarged. The observations of 1907 were confirmed; no trace of the missing limestones was discovered; and the conglomeratic portion of the Quarry Ridge Grits was proved to rest directly upon the Olenellus Limestone, and yielded fragments referable to *Paradoxides*; while the Olenellus Limestone[1] yielded many of the fossils found in the same bed in the Quarry Ridge.

[1] This limestone and associated sandy rock has a somewhat different aspect from that of the quarry. The characteristic reddish-purple nodules are there, but the remainder of the bed might be described as a green, calcareous and micaceous sandstone.

Fossils :—

Olenellus, many fragments, some of which are referable to *O.* (*Holmia*) *Callavei*, Lapw.
Microdiscus Helena, Walcott.
Ptychoparia (?) *Atteboroughensis*, Schaler and Foerte.
Kutorgina.
Linnarssonia.
Stenotheca rugosa var.
Mickwitzia (?).

It seems probable that, prior to the deposition of the *Paradoxides*-bearing Quarry Ridge Grits, the Black and Grey Limestones had been denuded at this point, but in such faulted ground the evidence is not conclusive.

Close to Excavation No. 12, of 1907, in the disused quarry, at the south end of Dairy Hill, I found some fragments of grit in the soil, indicating the possibility that the grits might be found there in contact with the supposed Lower Comley Sandstone.

Further excavation was therefore made at this point, and a north and south section, some 14 yards in length, was exposed, the beds dipping about 10° to the west.

The upper part of the section shows 3 feet of bedded grit, similar to that of the upper portion of the Quarry Ridge Grits, resting conformably upon and graduating into some 10 feet of soft micaceous green sandstone, many of the beds of which are characterised by rusty circular spots.

No fossils were found in this section, and it is impossible at present to assign these rocks to any previously described portions of the Comley Sandstone Series. The transition from grit to sandstone appeared to be complete, with no sign of either unconformity or faulting.

In the hope of throwing further light on these Dairy Hill beds, a number of trial holes were made on the surface of the field and the results mapped in detail; but no definite opinion as to the succession could be formed.

It is at present very doubtful whether the micaceous green sandstones belong to the Lower Comley Sandstone, and it is also uncertain whether the grits are part of the Quarry Ridge Grits.

Further excavations, either here or at other spots in the Comley area, are required before the positions of these beds in the Comley Sandstone Series can be satisfactorily determined.

Shoot Rough Road Excavations.

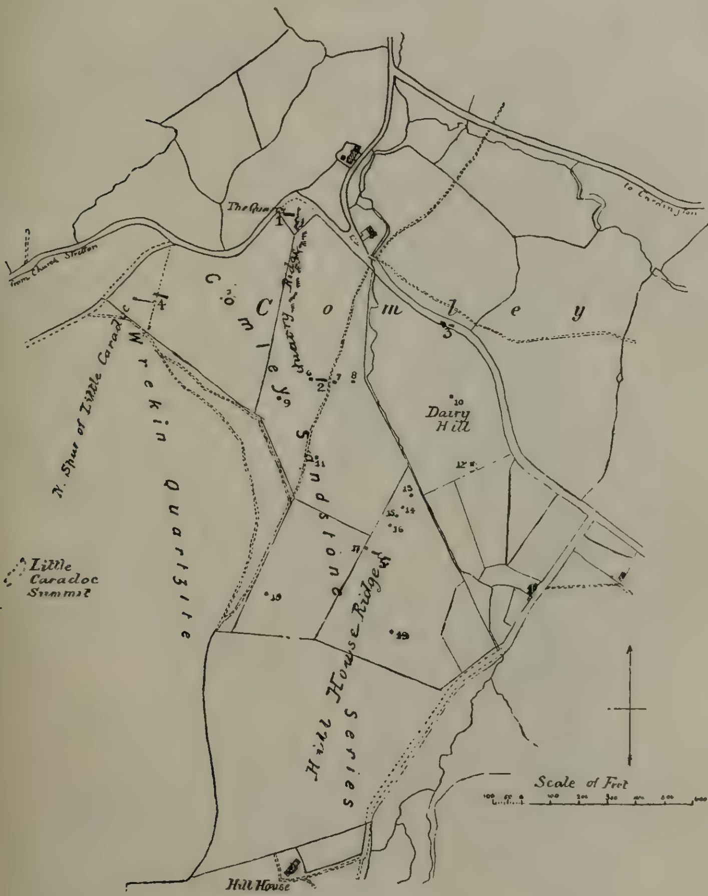
Previous excavations had been directed to the elucidation of the relations between the lower part of the *Paradoxides* beds and the *Olenellus* zone below. The excavations now to be described are in strata of a considerably higher zone, probably near the top of the *Paradoxides*-bearing division of the Cambrian.

On reference to the north-east corner of the sketch-map a road may be seen leading eastwards to Cardington. This is the Shoot Rough Road.[1] It ascends eastwards on ground which slopes southwards to a small stream,

[1] So called because it passes (beyond the limits of the map) between the Shoot Rough Wood and Shoot Rough Farm.

and its north side, being cut into the soil, touches rock at two portions of its length.

Both these exposures were much overgrown; the upper one, which is on the field side of the hedge, showed shale in association with gritty



Excavation No. 20. Shoot Rough Road, Upper Section.

flags, in which Professor Lapworth had previously found fragments of trilobites; the lower exposure consisted of sandstones, grits, and shales seen only in the road gutter, and from somewhere in this lower length Professor Lapworth, in company with Mr. Rhodes, had collected *Orthis Christianiæ*, Kjerulf (or a closely allied form). The exposures were opened up by excavation, and the following sections displayed.

The length in an east and west direction is about 24 yards.

The beds dip about 50° to the north-east, except at the western end, where a slight anticlinal fold sets in, bringing the dip round to nearly north.

E.S.E. End of the Section.

	Ft.	In.
a. '*Shoot Rough Road Shales.*'[1]		
Bluish-grey micaceous shale, weathering brown, a good deal crushed but clearly conformable with the underlying beds, and containing some very thin ($\frac{1}{8}$ or $\frac{1}{16}$ inch) coal-black seams, and a few hard siliceo-micaceous bands ($\frac{1}{4}$ to $\frac{1}{2}$ inch thick) near its base (top not seen)	12	0
b. '*Shoot Rough Road Flags*':—		
A series of coarse, glauconitic, gritty flags, in places calcareous and varying in thickness from $\frac{1}{9}$ inch to 12 inches.		
b_1 Dark brown or black sandy rottenstone, flaggy in places . .	1	0
b_2 Thin sandy shales or shaley flags	1	0
b_3 Shaley flags, thicker, with a few fossils	2	6
'*Acrotreta* (?) sp., cf. *Sabrinæ*, var. *malvernensis*, Matley.'		
b_4 Coarse gritty calcareous rock with pebbles of quartz and other rocks, crowded with *Acrotreta*	0	6
'*Acrotreta socialis*, von Seebach.'		
'*Acrotreta* (?) sp., cf. *Sabrinæ*, var. *malvernensis*, Matley.'		
'*Acrothele* (?) sp., cf. *granulata*, Linnrs.'		
'*Kutorgina cingulata*, var. *pusilla*, Linnrs.'		
'*Obolella* (?) sp., cf. *Salteri*, Holl.'		
'*Obolella* (?) sp.		
'*Orthis Lindströmi*, Linnrs.'		
Agraulos (?) (freecheek only).		
Paradoxides sp., cf. *P. Davidis*, Salter.		
A coral.		
b_5 Coarse gritty flags with round or elongate black nodules, (?) phosphatic	1	0
b_6 A well marked ochreous sandy bed containing residual nodules of gritty limestone	0	6
'*Acrotreta socialis*, von Seebach.'		
'*Obolella* (?) or *Acrotreta* (?) sp. (with low concentric ridges).'		
'*Lingulella feruginea*, Salter.'		
'*Orthis Lindströmi*, Linnrs.'		
Agnostus fallax, Linnrs.		
Agraulos sp., cf. *holocephalus*, Matthew.		
Agraulos sp.		
Microdiscus, fragment only.		
Paradoxides Davidis, Salter.		
Solenopleura (?) sp., cf. *brachymetopa*, Angelin (small).		
b_7 Gritty flags (base not seen)	5	6
'*Orthis* sp., approaching *O. Hicksi*, Salter. This species differs from the St. David's form in the fewer interpolations of ribs between the principal radii and in the small size of the umbonal cavity.'		
Total thickness seen . .	24	0

W.N.W. End of the Section.

No rock was found for about 80 yards along the road between the upper and lower sections.

Excavation No. 21. *Shoot Rough Road, Lower Section.*

A narrow horizontal plan of the strata was exposed by clearing out the road gutter and stripping the soil from the foot of the adjoining bank,

[1] These must not be confounded with the shales of Shoot Rough Wood, from which an undetermined *Dictyonema* was collected some years ago by Mr. Gibson.

a deeper excavation being made here and there. Only the surface aspect of the rocks could be seen, and it is quite possible that the dips and strikes observed, and the thicknesses of the beds deduced therefrom, may be somewhat inaccurate. The easterly dip of the shales at the western end of the section is taken to be a reversed westerly dip, due either to surface creep down the natural slope of the ground, or to actual inversion of the strata.

The beds are described from west to east as probably representing the descending order of succession.

In order to identify in the future the exact positions of the beds of this section, which is certain to be overgrown in a year or two, measurements were taken along the gutter from the stile in the fence where the footpath (Comley to Lawley Hill) crosses the road; these distances are given in the left-hand column of the following description:—

W.N.W. End of the Section.

Distance from stile in feet.		Estimated thicknesses of beds in feet.
156	At this point there is a grating for rain water in the gutter.	
156 to 200	Signs of shale in the soil but no solid rock.	
200 to 250	*a.* Shale, cf. *Shoot Rough Road Shales* of the upper Section.—Pale bluish-grey shale, weathering brown, containing much mica and several hard bands (½ to ¾ inch thick) of siliceo-micaceous material, one of which (at 224 feet) yielded brachiopods. The strike is at first N.N.W. and S.S.E., with an easterly dip of about 75°, but, in the last 6 or 8 feet of the shale, the strike works round to nearly N. and S. with a vertical dip . . . . . about	30
	'The dominant form is a minute ribbed *Orthis* with lobe on pedicel valve and a sinus on brachial valve. It approaches the Upper Lingula Flag form *Orthis lenticularis*, Wahl, but is smaller and probably a distinct variety. The fossils are preserved as casts in the shaley sandstone, which does not lend itself to the preservation of the delicate characters of the minute fossils. There are other species present, including probably *Kutorgina* sp. and a small *Acrothele*.'	
250 to 272	*b.* Gritty flags. Cf. *Shoot Rough Road Flags* of the upper section.—Thin grits or gritty flags with dark rottenstone bands. The strike is at first N. and S. with a high dip, conformable with the shales, but it works round gradually to about N.E. and S.W. with a north-westerly dip of about 45°	12
272 to 273	*c.* Yellowish clayey material, possibly indicating a fault, but, equally possibly, some decomposed calcareous band .	1
273 to 291	*d.* Soft green micaceous sandstone (in many respects resembling the Lower Comley Sandstone), rather flaggy and with some rottenstone bands. The strike is parallel with that of the gritty flags, *b*, and the dip north-westerly at 30° to 40°	10
	Total estimated thickness . .	53
294 to 354	The roadside was stripped of soil for a further distance of about 20 yards, but no more rock was laid bare.	

E.S.E. End of Section.

From a measurement given me by Professor Lapworth, it appears that his specimens of *Orthis Christianiæ*, Kjerulf (?), were found at about 310 feet on the above section.

Excavation No. 22.—50 yards North-West of the Comley Quarry.

There is a prominent boss in the field lying north-west of the quarry, which proved on excavation to contain a quartzite agreeing very closely with beds b_1 and b_2 of Excavation No. 4, 1907, in the northern spur of Little Caradoc (see previous report). The rock is much fractured, but exhibits a north-easterly dip of 60° to 70°.

Further trials were made in the field between this excavation and the quarry, but failed to reach solid rock.

Remarks.

From a consideration of the fossils found in the Shoot Rough Road excavations it seems probable that a local shaley representative of the Lingula Flags has been touched, and that the upper limit of the *Paradoxides* division has been reached. Shale with *Dictyonema*,[1] which may be of Tremadoc age, is known to occur within a horizontal distance of 200 yards north of the sections, and may be nearer, and in 1901 the Upper Lingula Flags species, *Orthis lenticularis*, Wahl, was collected by the Rev. W. M. D. La Touche and myself from a calcareous nodule in shale within 70 yards in the same direction.[2]

It therefore seems very desirable to extend the excavations across the intervening ground, so as to establish, if possible, the local sequence of the middle and upper divisions of the Cambrian rocks.

The lower limit of the middle division and the upper surface (probably eroded) of the lower division have already been fixed within a few inches (see previous report [3]). It is anticipated that further excavations at other spots in the Comley area may throw additional light upon the details of the zones of the middle and lower divisions and upon the nature of the base of the latter, which was only approximately indicated in Excavation No. 4 of 1907.

I have to acknowledge the very kind response made by Dr. C. A. Matley to my request for help with the brachiopods, who tells me that his determinations must be regarded as provisional. In the lists of fossils I have placed his identifications and remarks within quotation marks.

I am also again indebted to Mr. Philip Lake for assistance in the determinations of the trilobites.

[1] See footnote, p. 184.

[2] *Caradoc Record of Bare Facts for* 1901, Caradoc and Severn Valley Field Club, Shrewsbury, 1902.

[3] *Brit. Assoc. Reports*, 1908 (*Dublin*), pp. 342, 343, 1909.

Faunal Succession in the Lower Carboniferous Limestone (Avonian) of the British Isles—Report of the Committee, consisting of Professor J. W. GREGORY (*Chairman*), Dr. A. VAUGHAN (*Secretary*), Dr. WHEELTON HIND, *and* Professor W. W. WATTS, *appointed to enable* Dr. A. VAUGHAN *to continue his Researches thereon.* (*Drawn up by the Secretary.*)

REPORT by Dr. A. Vaughan on his work during the year 1908-09:—

South-Western Province—Gower.

The paper by Mr. E. E. L. Dixon, B.Sc., F.G.S., and myself on the 'Carboniferous Limestone of the Gower Peninsula' is finished, and awaits publication.

South-Western Province—Burrington Comb (Mendip).

A detailed account of this important section—already sketched out, in its broad faunal features, by Dr. T. F. Sibly, F.G.S.—is in preparation by Prof. S. H. Reynolds, M.A., F.G.S., and myself. The paper will include a full account of the various rock-species, zoned views of the section, and a minute exposition of the coral sequence in the Tournaisian.

The Bernician Sequence of Northumberland. By STANLEY SMITH, *M.Sc., F.G.S.*

I have devoted a small portion of the grant to preparing and photographing a few important coral groups which characterise the uppermost division ('Yoredales') of the Limestone in the Northern Areas (the level indexed D_y in the accompanying tables). Mr. Smith has kindly promised to insert these figures in his forthcoming paper in order to demonstrate the progression of the coral fauna upon that of D_2 in the S.-W. Province.

County Dublin—Malahide.

The description and illustration of the Tournaisian Beds of this fine coast section will be the subject of a paper by Dr. C. A. Matley, F.G.S., and myself in the coming year.

Under the guidance of, and with the assistance of, Prof. G. Delépine, of the Catholic University of Lille, I hope to devote the summer vacation of this year to an examination of the Belgian sequence, and to an exact correlation of the divisions recognised by Belgian geologists with the Avonian zones. For this purpose I hope that this Committee and grant will be continued for yet another (and final) year.

Tables drawn up by Dr. Vaughan to exhibit the Present State of Knowledge of the Avonian in the British Isles.

Table I. exhibits the zones and sub-zones of the Avonian, and the corals which characterise and diagnose them.

In Table II. I have attempted to assign to the several phasal developments their correct position on the Avonian scale.

Table III. gives the zonal sequence at several points in the British Isles. In almost all cases I have seen the material on which these correlations are founded, and my thanks are tendered most heartily to those workers who have allowed me to present the information contained in this table before its actual publication elsewhere.

TABLE I.

The **Avonian** ZONES and SUBZONES and the **Corals** that characterise them.

THE ZONES.

VISÉAN.

Dibunophyllum Zone (D).
Dibunophyllum enters and attains a maximum.
Lithostrotion junceum enters and is common throughout.

Seminula Zone (S).
Lithostrotion enters and is continuously abundant.
Carcinophyllum enters and is not uncommon.
[Maximum of *Seminula ficoides.*]

Syringothyris and **Caninia Zone (C).**
Giganteid *Caniniæ* enter and attain a maximum.
Michelinia grandis enters and attains a maximum.
[The maximum of very large *Syringothyris.*]

TOURNAISIAN.

Zaphrentis Zone (Z).
Simple *Zaphrentes* (of non-Caninoid and of non-Densiphylloid types) enter and attain a maximum.
Michelinia favosa attains a maximum at extinction.

Cleistopora Zone (K).
Cleistopora occurs throughout, but is common at only a few levels.

THE SUBZONES

VISÉAN.

Of the *Dibunophyllum* Zone (D).

D_y :—
Lonsdalia duplicata enters and attains a maximum.
Cyclophyllum attains a maximum.
Koninckophylla of the typical group attain a maximum, and include compound forms.
Diphyphyllum gracile enters.

D_3 (‘*Cyathaxonia*’ Beds) :—
Cyathaxonia rushiana.
‘*Cyathaxonia*’ *contorta.*
Zaphrentis oystermouthensis.
Michelinia favositoides.

D_2 :—
Lonsdalia floriformis enters and attains a maximum.
Cyathophyllum regium (a compound Clisiophylloid species) enters and attains a maximum.
Diphyphyllum lateseptatum enters.

D_1 :—
Dibunophylla and *Koninckophylla* of simple structure enter and attain maxima.
Carcinophyllum θ attains a maximum at extinction.
Cyathophyllum murchisoni (a Clisiophylloid species) attains a maximum.
[*Productus giganteus* enters—1st maximum.]

Of the *Seminula* Zone (S).

S_2 [a mutation of *Productus* ‘*Cora*’ indexes the subzone] :—
Carcinophyllum θ enters and becomes common.
[The entrance of *Cyrtina carbonaria* marks the base in the S.W. Province].

S_1 :—
Carcinophyllum mendipense enters.
Caninia bristolensis (a Cyathophylloid species) attains a maximum.
Clisiophyllum ingletonense attains a maximum.

Of the *Syringothyris* Zone (C).

C_2 :—
Cyathophyllum ϕ (a Caninoid species) enters and attains a maximum.

TOURNAISIAN

C_1 :—
Caninia n.sp. is characteristic of the base (γ).
Caninia cornucopiæ attains a maximum.
Cyathophyllum patula (a Zaphrentoid species) enters and attains a maximum.

Of the *Zaphrentis* Zone (Z).

Z_2 :—
Zaphrentis konincki enters and attains a maximum.
Zaphrentis omaliusi abundant.
Caninia cornucopiæ enters.

Z_1 :—
Zaphrentis delanoui attains a maximum.
[Maximum of *Spirifer clathratus* and *S. tornacensis.*]

Of the *Cleistopora* Zone (K).

K_2 (maximum of *Spiriferina* cf. *octoplicata*) :—
Cleistopora attains a maximum.

K_1 :—
[*Productus bassus* enters and attains a maximum.]

N.B.—The information enclosed in square brackets regards the Brachiopod sequence; only those facts which are diagnostic of zones or subzones are introduced.

Note on D_y and D_3 :—

D constitutes the continuation and apotheosis of the earlier D_2 fauna; it is typically expressed in the fauna of the ‘Main Limestone’ of the ‘Yoredales.’

D_3 connotes a phasal fauna later than the beginning of D_2, and contemporaneous, in part, with D_y. An extension of this fauna is, locally, intercalated in the ‘*becheri* Beds’ of the Lower Pendleside (P).

TABLE II.

Phasal Equivalents of Avonian.

← *increasing depth* →

	Standard Fauna	Zaphrentid *and* Cyathaxonid-*Phases*	*Modiola- and Posidonomya-Phases* and other shallow water deposits	
VISÉAN	Dy {('Yoredales') (E. Midlands) (N. Wales)}	*Cyathaxonia*-fauna intercalated in P (Loughshinny, Co. Dublin)	Zone of *Glyphioceras spirale* Zone of *Nomismoceras rotiforme* and maximum of *Posidonomya becheri* Zone of *Prolecanites compressus*	P Lower PENDLESIDE of Hind and Howe
	D_2 {(Avon Section) (Top of Great Scar)}	D_2 '*Cyathaxonia* Beds' :— {(Bradbourne, Derby) (Rush, Co. Dublin) (Oystermouth, Gower)} *Cyathaxonia*-fauna intercalated in D_2 (Bullslaughter Bay, Pembroke)		
	D_1 (Bristol Area)	Beds containing *Zaphrentis ambigua* (Lane Limestone, near Rush, Co. Dublin, and Colne Limestone, Lancs.) probably lie at this level		
	S_2 (Avon Section) conditions variable to quite shallow			
	'*Caninia* Beds' C_2—S_1 {(Near Frome, E. Mendip) (Stack Region, Pembroke)}	'*Bellerophon* Beds' (Bristol and Tenby Areas)	Plant Beds (Chepstow) Beds containing *Modiola*, &c. (near Kidwelly, S. Wales) '*Mitcheldeania* Beds' (Bristol, Forest of Dean)	
TOURNAISIAN	'*Caninia* Beds' γ-C_1 (Burrington Comb, N. Mendip) (Waterlip, S. Mendip)	Deposits at this level oscillate from standard conditions, γC_1, through a Zaphrentid Phase, into Dolomites (the '*laminosa*-dolomite' of the S.W. Province)		
	Z_2 ('Black Rock,' Avon Section)			
	β-Z_1 ('Black Rock,' Avon Section)			
	K_2 (Cook's Folly, Avon Section)			
	K_1 (Cook's Folly, Avon Section)		Km '*Modiola* Beds' (Avon Section) a transitional series from the OLD RED SANDSTONE	
	[No marine representative in the British Isles of the Famennian of N. France]			

N.B.—Typical localities are enclosed in brackets; these are merely selected from a great number of equally suitable references.

The zones of the Lower Pendleside are those cited by Dr. Wheelton Hind ('Brit. Assoc. Report,' York, 1906, p. 311), and the correlation of P with the '*Cyathaxonia* Beds is made by Dr. Hind himself in the same report; he is, however, in no way committed to the correlation with Dy given above.

The terms Tournaisian and Viséan have been retained here and the dividing line between them has been made to accord with the level of initiation of unconformity demonstrated by Mr. Dixon for the South-West Province. If this course is regarded as unwarrantable, the terms Clevedonian and Kidwellian must be carefully redefined and adopted in place of the well-known Belgian terms.

…and W. Midlands	Co. Dublin	Co. Clare
…one Grit …Beds' P …axonia Beds' D_3 D_2 and 'Brachiopod Beds' of Welton	'spirale Shales' Cyathaxonia fauna intercalated in 'becheri Limestones' D_3 'Cyathaxonia Beds,' Rush D_2 Dibunophyllum Limestones and 'Brachiopod Beds' of 'Curkeen' Limestone Rush Lower Pendleside P — Loughshinny	D_3 and Dy D_2
D_1	? age — Lane L. and Conglomerate (Rush)	D_1
? ? Base not seen		S_2
	megastoma-Beds of Rush Conglomerate	C_2–S_1
	? age — ? 'Waulsortian' fauna of St. Doulagh's Quarry	C_1 'Waulsortian'
	γ, Z_2, Z_1 — Malahide Section	Z
	K — Seen near Swords	K
	Conformity O.R.S.	probable conformity O.R.S.
Sibly: 'Q. J.,' vol. lxiv. …08)—Midland Area. …lton Hind: References … Collection.	C. A. Matley and A. Vaughan: 'Q. J.,' vol. lxii. (1906)—Rush. 'Q. J.,' vol. lxiv. (1908)—Loughshinny. Forthcoming paper—Malahide.	J. A. Douglas; 'Q.J.,' vol. lxv. (1909)—Co. Clare.
Remarks. …'*becheri* Beds' lie, at …n the main, *above* D_3. … 'Brachiopod Beds' …ll Phase') appear, in … to represent D_3, and Dy … typically developed in …calities exhibiting this …lar phase.	*Remarks.* The *Zaphrentis ambigua* beds of Lane are certainly below D_3, but may extend zonally a little lower than D_1. (The massif of Colne, Lancs,† is probably of the same age.) The *megastoma*-Beds of Rush may be of the same or earlier age than the Lane conglomerate. The suggested horizon of the famous St. Doulagh's Quarries is deduced from the practical identity of their fauna with that of 'the Waulsortian' of Co. Clare described by J. A. Douglas. † A. Wilmore: forthcoming paper—Colne Area, Lancs.	

…e ample material which they have kindly allowed me to examine.

Table III

ADDENDUM.

Examples of Use of Zonal Scale.

Evolutionary Phenomena illustrated by the Coral Sequence.

Phylogenetic old age is indicated by a vesicular and indistinctly septate peripheral zone—as in *Caninia gigantea* and in *Lonsdalia*.

Compound forms succeed simple ones and, probably, to all compound species there is a simple ancestor: *Cyathophyllum regium* is the culmination of the *Cyathophylla*; simple *Lonsdalia* precedes (in D_1), and accompanies (in D_2), the entrance of '*Lonsdalia floriformis*'; *Lonsdalia duplicata* is a compound and specialised *Dibunophyllum*.

Parallel development is illustrated in the closely allied genera *Lithostrotion* and *Diphyphyllum*; the very narrow *Diphyphyllum*, *D. gracile* of D_y, succeeds the broad *D. lateseptatum* of D_2, just as the very narrow *Lithostrotion*, *L. junceum* of D, succeeds the broad *L. martini* of S.

Coeval assimilation is exhibited by the *Cyathophylla* which are Zaphrentoid (*C. patula*), Caninoid (*Cyath.* ϕ), or Clisiophylloid (*Cyath. murchisoni*), according to the dominant 'tone' of the age.

Direct and continuous variation is exhibited in the *Koninckophylla* from D_1 to D_y, in the *Cyathophylla* from γ to D_2 and in the *Dibunophylla*.

Persistence of species is illustrated by the great Clisiophyllid trunk-line. Already highly developed in *C. omaliusi* of the Uppermost Devonian, this gens of *Clisiophyllum* reappears in γ, becomes common in C, and attains a maximum (in a well-marked variant, *C. ingletonense*) at S_1; it still persists into D_y, where the difference from the Devonian ancestor is remarkably small. *Caninia cornucopiæ* is another example; the gens starts at the top of Z, reaches a maximum in early C, and reappears, in D_2 and D_y, in a mutation which differs but slightly from the early form.

Acceleration of variation on approaching extinction is beautifully illustrated by the large number of closely linked sub-genera into which the main Clisiophyllid section divides in D_y, *e.g.*, *Aspidophyllum*, *Rhodophyllum*, *Histiophyllum*, *Cymatiophyllum*, *&c.*

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Professor S. J. Hickson (*Chairman*), Rev. T. R. R. Stebbing (*Secretary*), Sir E. Ray Lankester, Professor A. Sedgwick, Professor W. C. McIntosh, Dr. S. F. Harmer, *and* Mr. G. P. Bidder.

The table at the Zoological Station at Naples has been fully occupied during the past session. Thanks to the kindness of Dr. Dohrn two or more nominees of the British Association Committee have, on occasions, been allowed to work in the station at the same time.

The following naturalists have occupied the table since the date of our last report:—

Mr. W. J. Dakin, B.Sc., University of Liverpool.
Mr. H. O. S. Gibson, B.A., University of Oxford.
Colonel Shepherd, Indian Army.
Mr. F. F. Dreyer, B.A., University of Cape Colony.
Mr. Charles Martin, B.A., University of Oxford.

Mr. H. O. S. Gibson occupied a table from the beginning of November, 1908, until April 23, 1909. His investigations consisted in an attempt to habituate Mysis to live in increasingly fresh water with a view to tracing possible changes in structure due to the change in environment. He also spent some time in investigating the digestion and secretion of Squilla mantis, and will pursue the subject further on the material prepared at the station and brought home with him.

Mr. W. J. Dakin sends in the report which is appended.

Colonel Shepherd occupied the table from the end of October until March 10, and collected a large number of the otoliths of fishes with the view to the publication of a memoir on these structures. He also collected a number of specimens of the pharyngeal teeth of fishes, upon which he proposes to publish a series of papers at a later date. He writes to the Committee to say that it would have been impossible for him to have made so much progress with the investigation he has in hand but for the opportunities and assistance he received at the Zoological Station at Naples.

Mr. F. F. Dreyer arrived at the station at the beginning of April and was still there at the time of the receipt of his report. He carried on some investigations on the nervous system of the Æolididæ. He has obtained the best results by using Apathy's method of preserving and mounting, and has already obtained some interesting results. His work is not yet sufficiently advanced to enable him to send us a detailed report, but he hopes to be able to publish a paper on the nervous and blood-vascular systems of the Æolididæ at the end of the year.

Mr. C. Martin visited the station during the Easter vacation in order to continue his investigations on the structure of the Acinetaria.

With reference to the report of last year, the Committee would refer to the important paper published by Mr. C. Clifford Dobell in the 'Quarterly Journal of Microscopical Science,' Vol. 53, 1909, on the Infusoria Parasitic on Cephalopoda. This paper represents a part only of the work done by Mr. Dobell during the time he occupied the Association's table at Naples last year.

Mr. Whitehouse has prepared a large and important memoir on the structure of the caudal fin of fishes, which has been submitted as a thesis for the degree of M.Sc. of the University of Birmingham. It will be published shortly.

In conclusion, the Committee wish to call attention to the increasing volume and importance of the original work that is done by the occupants of the Association's table at Naples, and ask to be reappointed with a grant of 100*l*.

Report of Mr. W. J. Dakin, *B.Sc.*

The following is a brief *résumé* of the research I was engaged in whilst occupying the British Association table at the Zoological Station of Naples during the past winter. I arrived in Naples on November 1 and left at the end of February, so that I occupied the table for four months. The latter part of the time was devoted mainly to the collection and preservation of material for continuation of the histological work at home, the earlier part of my stay to an elaboration of methods.

I have, unfortunately, not been able to work at my slides or other material since I arrived back in England owing to pressure of work in

conjunction with Plankton and Hydrographic Research, and for that reason the report is rather incomplete as regards final results. I hope to have complete papers published by the end of this year, in which due acknowledgment to the British Association will be made, and copies will be handed to the Committee. I feel it my duty to thank the British Association for the opportunity of working at Naples, and must also mention the kind way in which the various members of the staff of the Zoological Station gave every possible help. The researches dealt in general with the histology and physiology of the nervous system and sense organs of lamellibranchs, continuing my previous work on Pecten. Though forty-four years have elapsed since the first detailed work on the eye of Pecten, it still remains incompletely known, owing to the extreme technical difficulties. I intended, therefore, to make a fresh and complete comparative study of the structure of the Pecten eye, using the new methods which have elucidated so many points in the structure of invertebrate sense organs in the last few years.

Another branch was the study of the visceral ganglion and the innervation of the osphradium. The former is particularly interesting in Pecten, and unique as regards complexity in the Lamellibranchiata. I hoped to trace the distribution of the nerves in the ganglion in order to make out whether definite regions were concerned with the innervation of separate organs, and finally to consider in detail the histology. With regard to the eye, it would be impossible here to discuss at all fully the histological structure without figures, but the following points may be noted. Hesse was able to see a layer of fibres lying between the cornea and lens, and bases a theory of accommodation on their presence (they stain, according to him, as muscle fibres), together with a peculiar structure in the lens cells. I find no trace of accommodation in the Pecten eye, and histological evidence points to these fibres being of connective tissue. I have been able to find between the cornea and lens numerous connective tissue cells which are produced into the extremely long fibres seen by Hesse.

Certain points remain to be added to the known structure and shape of the lens cells. The axial fibril of the rod is with certainty a continuation of a fibril in the rod cell. It is thicker in the former, and often remains in macerated specimens when the rest of the rod has been disintegrated.

There is a growing region for rod cells and rods round the periphery of the retina, and the axial fibril is always far more distinct in the young cells than in those from the middle of the retina. There are large and small eyes often in close proximity on the same valve; the difference between these is simply the number of the elements—small eyes have fewer rod cells and rods. In most ways the axial fibril does not display the characters of a neurofibril, and may possess simply a supporting function. Numerous delicate supporting fibrillæ run longitudinally down the rod cells arranged at the periphery. The eyes are innervated directly from the visceral ganglion.

The visceral ganglion consists of two central prominent lobes, with one or two smaller ones at their sides, a lobe partially covering the two first mentioned, and two large lateral crescentic lobes. I have made out the roots of the various nerves in detail. The branchial nerve arises by two roots. A separate nerve arising from the upper side (the surface against the adductor being considered the lower) innervates the

osphradium. Some of its branches pass directly to the osphradium, another one joins the branchial nerve, from which nerves pass to the osphradial epithelium.

The two large lateral lobes are extremely interesting. They are not found in other lamellibranchs. The nerves arising from them innervate the mantle folds. In *P. jacobæus* the eyes are more numerous and larger on the left valve, those on the right valve being small. The same difference exists between the two lateral lobes of the visceral ganglion in size. In *P. maximus* and *P. opercularis* the same difference in size of the two lobes corresponding to the number of eyes on the mantle folds exists, and in the three species examined the relative difference between the two sides is parallel with that of the number and size of the eyes on the mantle folds. From this alone it might be safely assumed that the lateral lobes of the visceral ganglion are due to the development of eyes on the mantle and are concerned with the innervation of these. This view was strengthened by the discovery that in several cases the nerve fibres passed direct from the visceral ganglion to the eyes. The eyes were formerly supposed innervated solely by the circumpallial nerve.

The osphradium in Pecten, Arca, and Mactra, the species so far examined, is innervated by the visceral ganglion. It was in the latter species that Pelseneer obtained evidence of its innervation from the cerebral ganglia, and believed this to prevail throughout the Lamellibranchiata. I believe the innervation is always from the visceral ganglion, though *some* fibres may pass from the cerebral ganglion, through the visceral, and into the osphradial nerve. These, however, would be few in number, and in Pecten can only be seen passing into the branchial nerve. It is impossible to say at present whether the fibres passing from the branchial nerve to the osphradium contain any of these.

Whilst examining the mantle edges of *Pecten jacobæus* I was able to discover the presence of a transversely striated muscle similar to that present in the adductor muscle of Pecten. A short paper on these has been published this year in the 'Anatomische Anzeiger.' They occur *between* the eyes, and cause the rapid movements of the velum which take place and enable the animal to swim.

It is often difficult to start a Pecten swimming, for ordinary stimuli simply cause a closure of the valves. A starfish brought before the valves, however, immediately causes the animal to swim. The same effect can be produced by the injection of starfish pulp just between the mantle lobes. Similar injection of sea-water or water with small particles does not produce this effect. It is evidently not due to visual or tactile stimuli, and I am endeavouring at present to determine the action of the osphradium and abdominal sense organs in the perception of this stimulus.

Index Generum et Specierum Animalium.—Report of the Committee, consisting of Dr. HENRY WOODWARD (*Chairman*), Dr. F. A. BATHER (*Secretary*), Dr. P. L. SCLATER, Rev. T. R. R. STEBBING, Dr. W. E. HOYLE, Hon. WALTER ROTHSCHILD, *and* Lord WALSINGHAM.

STEADY progress has been made with the literature for the second portion of this Index (1801-1850). Among numerous works dealt with, the compiler, Mr. C. Davies Sherborn, specially mentions the following:—

Publications of the British Museum.
British Association Reports.
H. G. Bronn's works.
Publications of the Academy of Brussels.
Many editions of Buffon.
'Isis' (von Oken).
Gesellschaft deutscher Naturforscher und Aerzte.

As a matter of interest, it may be mentioned that 42,500 index-slips, in duplicate, have been made and arranged within the last two years. The Committee regards this as a surprising and satisfactory rate of progress, when it is remembered that it is entirely the work of a single individual.

All the index-slips, as arranged up to date, are accessible for reference in the library of the Geological Department at the Natural History Museum, Cromwell Road, London, where they are frequently consulted by zoologists, both in person and by letter. Thus, as the value of the Index increases with its daily growth, the time of the compiler becomes more encroached on by inquirers. On the other hand, the diminution of the grant during the past few years has been seriously felt by the compiler, and the Committee, while recommending its own reappointment, asks the Association to consider carefully the value of such a work of reference, and to give it the much needed help with a renewal of the grant of 100*l.*

Experiments in Inheritance.—Second Report of the Committee, consisting of Professor W. A. HERDMAN (*Chairman*), Mr. DOUGLAS LAURIE (*Secretary*), Mr. R. C. PUNNETT, *and* Dr. H. W. MARETT TIMS, *on the Inheritance of Yellow-coat Colour in Mice. (Drawn up by the Secretary.)*

THE experiments discussed in my last year's report are in progress. A detailed report would at present be premature. The Committee ask to be reappointed, with a grant of 30*l.*

Feeding Habits of British Birds.—First Report of the Committee, consisting of Dr. A. E. SHIPLEY (*Chairman*), Dr. C. GORDON HEWITT (*Secretary*), *and* Messrs. J. N. HALBERT, ROBERT NEWSTEAD, CLEMENT REID, A. G. L. ROGERS, *and* F. V. THEOBALD, *appointed to investigate the Feeding Habits of British birds by a study of the contents of the crops and gizzards of both adults and nestlings, and by collation of observational evidence, with the object of obtaining precise knowledge of the economic status of many of our commoner birds affecting rural science.*

THE Committee decided to investigate first the feeding habits of the rook, starling, and chaffinch. It has organised the following body of correspondents, who have very kindly promised to assist the inquiry by sending specimens of these birds to the Secretary each month, and the Committee desires to express its great obligation to the correspondents for the assistance they are rendering:—

Mr. T. A. Acton, Wrexham
Mr. A. Arnold, Hants
Miss E. V. Baxter, Fife, N.B.
Mr. R. M. Barrington, Co. Wicklow
Mr. M. D. Barkley, Huntingdon
Mr. P. A. Buxton, Essex
Mr. C. L. Burrows, Cumberland
Mr. A. H. Cocks, Henley-on-Thames
Mr. L. C. Cox, Somerset
Mr. E. Lloyd Edwards, Llangollen
Col. Wynne Edwards, Denbigh
Mr. C. Gamble, Edinburgh
Miss Garner, Warwick
Mr. A. G. Gavin, Fraserburgh, N.B.
Mr. R. Gurney, Norwich
Rev. J. St. Herbert, Llandrindod Wells
Mr. P. Horn, London, E.
Mr. C. Ibotson, Bucks
Mr. T. W. W. Jones, Moreton-in-Marsh
Col. R. O. Lloyd, Pembroke
Mr. E. N. Millington, Shropshire
Mr. W. A. Nicholson, Portobello, N.B.
Prof. C. J. Patten, Sheffield
Mr. R. Patterson, Co. Down
Mr. J. M. Pope, N. Devon
Mr. D. B. Robinson, Cumberland
Mr. F. Shillitoe, Hitchin
Mr. F. Smalley, Carnforth
Mr. B. Thornber, Cheshire
Mr. C. W. L. Tottenham, N. Wales
Mr. F. Wilde, Cheshire
Mr. J. S. Wroth, S. Devon

As the correspondents live in different parts of England and Wales, Scotland, and Ireland, and in different types of localities, birds feeding under a wide range of conditions are obtained.

The first birds were supplied in December 1908, and during the first six months (December 1 to May 31) 590 birds have been received, the number being made up as follows: rooks, 124; starlings, 278; chaffinches, 188. Each bird or batch of birds is accompanied by a form filled in by the correspondent giving the following details:—

Name of bird.
Date on which specimen was killed.
Hour of the day when specimen was killed.
Exact locality where specimen was obtained.
Character of land upon or near which it was shot.
General character of neighbouring land.
Is the land well cultivated?
What crops are grown in the locality?
Is the district wooded?
Are the fields bounded by hedges, dykes, or walls?
What was the bird doing when shot? (feeding, flying, etc.).
Weather. Type of weather prevailing.

Was the specimen a member of a flock? If so, state the approximate size of the flock.

Is the species abundant in the locality?

Has there been any increase or decrease during the past few years?

Date and hour of dispatch. General remarks.

From such data some idea as to the environmental conditions under which the bird was feeding and the available food-supply can be obtained.

The contents of the gizzards of these birds are being examined, analysed, and tabulated by the Committee, and the intestines are being examined for parasites. The data obtained by analysis are arranged on the tabulation forms under the following heads:—

Grain	Seeds other than grain
Fruits	Roots
Miscellaneous vegetable matter	

INSECTS.

(Injurious and useful insects are separated and indicated, and larvæ are particularly mentioned.)

Coleoptera	Lepidoptera
Hemiptera	Other Insects
Diptera	

Molluscs	Miscellaneous food
Other Invertebrates	Remarks
Other animal matter	

In addition to the above data, the weight of the bird and the condition and weight of the gizzard contents are recorded.

When in the opinion of the Committee a sufficient number of specimens of any one species have been examined, the results of the tabulations and the particulars supplied by the correspondents will be digested, arranged, and published.

In addition to the grant (5*l.*) made to the Committee by the Association, a grant of 50*l.* has been received from the Board of Agriculture and Fisheries to enable it to carry on the work, and Mr. Rogers has been appointed by the Board as its representative.

The Committee asks for reappointment, with a further grant, and with the addition of Professor F. E. Weiss, and of Mr. H. S. Leigh as Secretary in the place of Dr. Gordon Hewitt, who is compelled to retire.

The Zoology of the Sandwich Islands.—Nineteenth Report of the Committee, consisting of Dr. F. DU CANE GODMAN (*Chairman*), Mr. D. SHARP (*Secretary*), Professor S. J. HICKSON, Dr. P. L. SCLATER, *and* Mr. EDGAR A. SMITH.

THIS Committee was appointed in 1890, and has been annually reappointed. The publication of the results of the work of the Committee is now nearly completed. One part of the 'Fauna Hawaiiensis' has been published since the last report, and it is expected that the work will be finished within the ensuing year.

The Committee ask for reappointment.

Zoology Organisation.—Interim Report of the Committee, consisting of Sir E. RAY LANKESTER (*Chairman*), Professor S. J. HICKSON (*Secretary*), Professors G. C. BOURNE, T. W. BRIDGE, J. COSSAR EWART, M. HARTOG, W. A. HERDMAN, *and* J. GRAHAM KERR, Mr. O. H. LATTER, Professor MINCHIN, Dr. P. C. MITCHELL, Professors C. LLOYD MORGAN, E. B. POULTON, *and* A. SEDGWICK, Dr. A. E. SHIPLEY, *and* Rev. T. R. R. STEBBING.

DURING the past session the Committee have had several matters of importance under consideration, but it was not considered necessary to summon a general meeting of zoologists.

A meeting of the Committee was held in Cambridge on June 22, when it was decided to ask for reappointment without a grant.

Occupation of a Table at the Marine Laboratory, Plymouth.—Report of the Committee, consisting of Professor A. DENDY (*Chairman and Secretary*), Sir E. RAY LANKESTER, Professor A. SEDGWICK, *and* Professor SYDNEY H. VINES.

SINCE the date of our last report the British Association's table at the Plymouth Marine Laboratory has been occupied for a fortnight by Miss May E. Bainbridge, who was engaged in investigating the Copepod parasites of fishes. An application from Mr. J. S. Dunkerly for the use of the table during the month of August, for the purpose of investigating the life-history of the Flagellate Protozoa, has lately been granted.

Investigations in the Indian Ocean.—Fourth Report of the Committee, consisting of Sir JOHN MURRAY (*Chairman*), Mr. J. STANLEY GARDINER (*Secretary*), Captain E. W. CREAK, Professors W. A. HERDMAN, S. J. HICKSON, *and* J. W. JUDD, Mr. J. J. LISTER, Dr. H. R. MILL, *and* Dr. D. SHARP, *appointed to carry on an Expedition to investigate the Indian Ocean between India and South Africa in view of a possible land connection, to examine the deep submerged banks, the Nayareth and Saya de Malha, and also the distribution of marine animals.*

THE Committee have received the following communication from Mr. J. Stanley Gardiner, who has had charge of the work:—

The further expedition to the Indian Ocean, determined upon in 1907, has now been brought to a satisfactory conclusion. Accompanied by Mr. H. Scott and Mr. J. C. F. Fryer, I arrived at Seychelles

on July 10, 1908, leaving on October 8. I devoted my attention to the geography and biology of the islands of Silhouette (2,467 feet) and Mahé (2,993 feet). The former is twelve square miles in extent and the latter over fifty square miles. Both are formed of coarsely crystalline granite rock, cut up by dykes of fine-grained black rock, down which the rain has for the most part cut its watercourses. The amount of erosion is enormous, and the general topography of the islands is almost entirely to be ascribed to the action of weathering. In all there are twenty-seven granite islands of upwards of 150 square miles on the centre of a shallow (less than fifty fathoms) bank of over 20,000 square miles. My impression from a further study of the group is that the greater part of the bank must have been at one time granite land, and that the present marine and aerial erosive actions in progress are sufficient to account for its gradual conversion into a series of small islands standing on a relatively enormous bank.

The fauna and flora of Silhouette and Mahé were carefully studied, very large collections being secured. They have a continental facies, *i.e.*, the general appearance and variety of form which is usually associated with large land masses. Both are severely restricted as to number of genera and species, but not more perhaps than would naturally be expected from the cutting down of a large mass of land to a few scattered islands, and the consequent change, almost to complete uniformity, of climate that would result. Only about four square miles of the indigenous jungle now remain. It is of the tropical rain-forest type, and a century and a half ago undoubtedly covered the islands uniformly from the sea to their highest peaks. The conditions of a rain-forest are not altogether favourable for a great variety either of plants or of animals. The jungle that remains lies on mountain peaks, covered with almost perpetual mist, and possesses these conditions in their extremest aspects. Few of the plants have been killed out, many persisting by the streams, but scarce half of the insect fauna is likely still to survive. Introduced insects and spiders are everywhere, and have been peculiarly destructive to the indigenous forms, directly by killing them and indirectly by consuming their food.

In a former report I referred to evidence of a change of level of the islands of Mahé and Silhouette in respect to the sea. My investigations show an elevation of these islands, or a lowering of the sea, of at least twenty-five to thirty feet, or four to five fathoms. This could scarcely have been sufficient to affect the topography of the Seychelles group as a whole, but is an interesting phenomenon when taken in conjunction with the general slight elevation found in most of the island groups from Madagascar to India. No indication was found of any subsequent or previous subsidence, the possibility of which is contradicted by the whole topography of the Seychelles.

Mr. H. Scott devoted himself to the entomology of the Seychelles, spending two months in Silhouette, five months in Mahé, and a month in other islands. He camped for the most part of the time in the mountains, and devoted himself to the insects of the indigenous jungles, collecting them and working at their habits and life histories. His collections comprise about 50,000 specimens, which are now being sorted and mounted for examination by specialists. It is too soon yet to say anything about these collections, but it may confidently be

anticipated that half of the species will be new. The collections are at least large enough to be used for basing deductions as to the relationships of the Seychelles considered entomologically.

Mr. Fryer proceeded on our arrival to investigate Bird and Dennis, two coral islands on the north of the Seychelles bank. He remained a month in them, and then proceeded to visit the islands to the N.W. of Madagascar, left uninvestigated by the Percy Sladen Expedition in H.M.S. *Sealark* in 1905. It will be some years before his results can obtain final form, but I append his preliminary report on his investigations. Meantime I cannot refrain from expressing my high appreciation of Mr. Fryer's pluck and resource in carrying on his researches in these islands for six months, during which he never saw a white man.

During the past year the first volume of the results of the investigations (Trans. Linn. Soc., Vol. XII.) has been completed by the publication of the following reports:—The Madreporarian Corals: I.—The Family Fungiidæ (J. Stanley Gardiner); A List of the Freshwater Fishes, Batrachians, and Reptiles (G. A. Boulenger); Antipatharia (C. Forster Cooper); Amphipoda Gammaridea (A. O. Walker); The Stylasterina (S. J. Hickson and Helen M. England); Polychaeta.—Part I.—The Amphinomidæ (F. A. Potts); Marine Algæ (Chorophyceæ and Phæophyceæ) and Marine Phanerogams (A. Gepp and Mrs. C. S. Gepp).

The following reports have also been read at the Linnean Society and are in course of publication:—Marine Nemerteans (R. C. Punnett and C. Forster Cooper); Echinoderms (Professor Jeffrey Bell); Rhynchota (W. L. Distant); Cirripedia (Professor Gruvel); Further Amphipoda (A. O. Walker); Marine Mollusca (J. Cosmo Melvill); Land Mollusca of Seychelles (E. R. Sykes); Lepidoptera (T. Bambridge Fletcher); Alcyonaria (Professor J. Arthur Thomson); Amphioxides (H. O. Gibson); Further Chaetopoda (F. A. Potts); Penæidea, Stenopidea, and Reptantia (L. A. Borradaile); and Marine Deposits (Sir John Murray).

J. STANLEY GARDINER.

Mr. Fryer's Preliminary Report.

I arrived in Mahé about the middle of July, and after some delay, which enabled me to visit Bird and Dennis Islands, I left Mahé on August 22 for Aldabra, visiting *en route* the islands of Astove, Cosmoledo, and Assumption. These four islands, which all lie some 200 to 250 miles north (N.N.W.) of Madagascar, must be considered as very closely allied in regard to their structure and formation. It seems necessary to include in this group the islands of Farquhar, Providence, and St. Pierre, which I had no opportunity of visiting, but which were investigated by the previous expedition on H.M.S. *Sealark*.

ASTOVE.

I reached Astove on August 27, and left on September 1, hoping to revisit the island in January, in which, however, I was disappointed. The island is a perfect atoll, which has been elevated for at least 25 feet. It is some two miles long by one mile broad, with a single pass on the south-west, opening into a shallow lagoon. The basis of the land rim is entirely formed of coral rock, which almost everywhere shows clearly on the surface, though blown sand has in places formed small dunes.

The structure of the rock varies considerably, but as a whole is remarkable for the small amount of metamorphosis which has taken place. Even on the surface large fields of coral in natural position were frequently noticed, while on the face of the cliffs it was always obvious that the corals were still essentially in the same position as when under the sea. Rock consisting of a conglomerate of reef *débris* was not common, but was always more prevalent near the lagoon shores, pointing to the probability that the central portions of the atoll were dead before elevation. Metamorphosed rock was found in various parts of the western half of the atoll, and always contained a considerable proportion of phosphatic matter, derived presumably from guano. Of the latter substance, considerable deposits exist near the lagoon shore on the west, and in large natural pits in the rock scattered over the atoll.

The lagoon is very shallow, being only a few inches deep at low spring tides; the bottom is covered with a very fine white mud, which, on account of the small depth, is churned up by strong winds, making the water quite white and piling the shores with foam. The amount of material carried to sea by each tide must be very large. This fact, taken in conjunction with the obvious erosion of the cliffs which form the shores of the lagoon, points to a rapid increase in size of the latter. Islands in the lagoon only occur near the pass, and it seems certain that much of the atoll depression must have existed at the time of elevation. These features of the lagoon can only be explained by supposing that the pass is of very recent date, an hypothesis borne out by the character of the latter itself. It is narrow, with no marked channel, being almost dry at low tide. The bottom is rocky, and there is no live coral either in it or in the lagoon. The reef outside is narrow, and but slightly channelled by the escape of water from the pass. It is not composed of modern reef substance, but apparently of elevated coral rock. Live coral is absent, though a certain amount of Lithothamnia exists. A cursory examination of the reef in other places pointed to its structure being the same, though a greater amount of sand and Lithothamnia-covered *débris* were present, often bound together by beds of *Cymodocea*. Variations in level across the atoll were difficult to estimate, but the highest rock level (12 feet above high-tide level) seemed near the sea, with a varying gradient to the lagoon. The seashore is sandy on the west, with cliffs appearing here and there. The east coast I could not visit owing to lack of time.

The land vegetation consists of dense scrub, composed of large bushes and small trees near the lagoon, though to seaward it is formed rather by small shrubs and matted herbaceous plants. A small collection of plants, as also of animals, was made, but the short duration of the visit coupled with the season prevented any thorough collecting being attempted. The settlement is situated on the west coast; it is small, and the inhabitants are employed in catching turtle and cultivating a small coconut plantation, which is being tried, while a certain amount of maize and tobacco is grown on the share system.

COSMOLEDO.

This group was reached on September 1. It is an atoll also, but differs from Astove in having only a small proportion of its rim capped

with land and in being considerably larger. It has an extreme length of 9 miles and breadth of 7 miles. The circumference of the atoll is about 24 miles, and of this only 10 miles at most consist of land. The latter is divided up into eight main islands and numerous small islets, but of all these only two are inhabited. During my stay, which was only one of four days, I visited four of the larger islands, and on my return journey I again had two days on the atoll, which enabled me to cursorily examine two more islands and take a representative series of photographs.

The results of the two visits may be outlined as follows:—The islands in all cases are fundamentally of coral rock, though sand has been piled on to them by the wind, and in places has completely hidden the rocky base beneath sand dunes and ridges. The rock is typical elevated coral rock, and, with the difference that metamorphosis has been more extensive, much resembles that of Astove.

The island shores are either rocky or sandy, but in either case show unmistakable signs of rapid erosion. On one island (Wizard) the remains of a house, now in the lagoon, enabled me to calculate the extent of the erosion as being 15 yards since 1893, an average of a yard a year. Evidence of the former extent of the land was obtained from the islets and table-shaped rocks on the reef, and I have little doubt that at one time the atoll was almost entirely capped with a ring of land.

The lagoon has the greatest average depth of any atoll visited, though the channels in the Aldabra lagoon are deeper. There are no islands situated anywhere in it, and no suggestions can be made as to its former extent. The bottom is largely sandy, and there are signs of a tendency to replace the original rocky islands by sand shoals and cays. There are two passes through the reef; these are both situated on the southern side of the atoll. The reef was examined at a point on the south-west; the seaward edge was conspicuous for the vigorous growth of Lithothamnia; no live coral was observed in this zone. Inside the edge Lithothamnia were still abundant, but were chiefly encrusting forms found on broken pieces of dead coral flung on the reef. Passing to the lagoon was a sort of buttress zone, with channels and pools containing a little live coral. The lagoon at this point was very sandy, and almost dry at low tide.

The land vegetation somewhat resembles that of Astove on the rocky places, but is not so dense, and owing to the presence of large quantities of sand perhaps would be more like that of Farquhar. A large mangrove swamp exists on the lagoon side of the chief island (Menai). In the dry season the islands are much more parched and dried up than Astove, but during the wet season crops of maize seemed to flourish remarkably well. Guano has been found on several of the islands, and a considerable quantity exported, as well as phosphate rock, which was found underneath the guano. It was interesting to discover in the latter rock the eggs of the giant land tortoise, though unfortunately no remains were found to determine the species. A collection of land animals was made, and the fauna appears to be identical with that of other islands in this region. The settlement is small (twenty people) and the inhabitants employed as at Astove.

ASSUMPTION.

Assumption was reached on September 6. It, unlike the two previous islands, is not an atoll; it is crescent-shaped, about $3\frac{3}{4}$ miles long and from 1 to $\frac{1}{3}$ mile broad. In composition it is undoubtedly an elevated reef, corals in position of growth being easily observed, especially on the face of the cliffs and on the sides of pits in the rock, which form a marked feature of the island. Much metamorphosis has occurred in places in the interior of the island, producing a rock which usually includes a considerable proportion of phosphate, derived, as in the other islands, from a superficial deposit of guano. The conglomerate mentioned in relation to Astove is common, and confirms the impression that it is of the nature of the rock forming on recent reef-flats. Variations in level over the island were, owing to the thick bush, difficult to estimate, but judging from three tracks cut from east to west across the land, there is a slight ridge running north and south near the west shore with a maximum height of 20 feet, decreasing on each side to the common level (about 12 feet) of the island. In the south-east are large dunes (90 feet high) formed entirely of blown sand. The natural pits in the rock, before referred to, are most common in the interior of the island, but also occur within a few yards of the sea. They seem to owe their origin to imperfect consolidation of the reef at the time of growth. They vary considerably in size, the largest being 18 yards long by 14 yards wide by 3 yards deep, and the deepest 45 feet. Some contain salt water, and others are largely filled with guano, though in these salt water can be easily reached by digging; in all the water seems to fluctuate tidally, though in no case was any connection with the sea discovered, except that of free percolation. The sides of the pits are always being eroded and weathered, and consequently the latter are increasing in size. It was natural to consider whether a lagoon could be formed by this means, but the conclusion was in the negative, as there seemed no reason why the pits should connect more rapidly with each other than with the sea.

Guano is present in some quantity, especially on a large plain near the east coast, while many of the pits contain a large quantity. It undoubtedly has had a considerable influence on the rock below.

The land vegetation is a scrub, dense and thick in places, especially in the south-west, and thinning out to an open plain in the east. A curious occurrence is that of a growth of mangrove trees in three of the pits; as there seems to be no free subterranean connection with the sea it is difficult to explain their presence in an island so unsuited to them as Assumption. Two of the pits contain *Brugiera* and the other *Ceriops*. A further discovery in these pits was that of the remains of giant land tortoises, considerable portions of several specimens being obtained. One species appears identical with that of the present Aldabra tortoise, but it appears likely that a second species also existed. Of the present fauna little need be said except that it resembles that of the other two islands.

The settlement is quite recent and was made to work the guano. Green turtles are extremely plentiful, and until killed off will be a source of profit to the island.

On September 12 I sailed for Aldabra, but again visited the island on my return, spending two days in photography and checking previous observations.

ALDABRA.

I arrived in Aldabra on September 13, and, owing to the excessive drought, had perforce to confine myself mainly to geological investigation until the end of the period of south-east trade winds. The wet season commenced in November, after which month most of the plants were found in flower, while land animals, previously invisible, became fairly numerous. I had four camps—*i.e.*, on Michel Island, at Takamaka on Main Island, on Esprit Island, and on Picard Island—from which I examined every portion of the atoll. Owing to the dense and impenetrable scrub, exploration was always attended by considerable difficulty, as paths could only be cut at the cost of great labour; in addition I cleared several broad sections from the sea to the lagoon, in order to get a clear idea of the sequence of the rocks and vegetation and of the relative elevations.

The nature of the ground and of its vegetation is such that the land may be divided into four somewhat irregular zones, from the lagoon outwards, as follows:—

(1) Mangrove swamp—varying in size up to nearly a mile in maximum breadth.

(2) Champignon—the surface much metamorphosed, coral rock, usually with sharply defined dark portions, which appear to consist of guano included during metamorphosis. It has evidently been subjected to heavy rain denudation, its surface being a mass of points and pits. The vegetation is a scrub of *Pemphis acidula.*

(3) Platin—fairly smooth, composed mainly of coral fragments and reef *débris*, with a few shells, weathering into large flat slabs with soil accumulating in the crevices. In places are larger depressions, in which there are usually clumps of trees. The soil is guano, with a mixture of disintegrated rock. The vegetation is varied, containing numerous small bushes and trees, *Pandanus*, *Ficus*, *Euphorbia*, &c.; the fauna also is varied and comparatively rich.

(4) Shore zone—largely of blown sand, with a stunted and wind-swept vegetation; large clumps of *Pandanus*, *Tournefortia*, and *Scaevola* everywhere very numerous.

In a broad sectional clearing which I made at Takamaka, the seaward reef commences with a fissured edge, succeeded by a sand flat, the sand being bound together by beds of grass-like *Cymodocea*, its rhizomes greatly overgrown by Lithothamnia; the buttresses between the fissures are themselves largely covered with sand; live coral is almost absent; not far from the edge are a few small boulders of dead coral, all much encrusted with Lithothamnia; a few species of seaweed are found in the pools left at low tide. The landward edge of the reef is formed of cliffs, 12 feet to 15 feet high, just outside which is usually a small depression in the reef with 2 feet or 3 feet of water. The cliffs are sloping, not overhanging, and are divided into buttresses; they consist of a mass of corals cemented together with lime. The corals are all in the position in which they grew, and so perfect as to give the

impression that they are only just dead. On the landward side of the cliffs is a ridge, 2 feet or 3 feet higher, of grass-covered sand; this marks the seaward edge of the shore zone, which is about 250 yards wide, the sand being shallow and lying on a basis of coral rock. Then comes a rocky ridge, 4 feet to 6 feet higher than the shore zone, the rock more solid and less denuded; this, the highest part of the section, is some 25 feet above sea-level. From the landward side of this ridge the level gradually decreases to about 10 feet above sea-level. It passes into a zone of Champignon, which here lies outside the Platin zone, which latter extends to the mangrove swamp. The Platin is all very similar in appearance, except that it is more wooded near the lagoon; it terminates with a sharp drop through the last 4 feet or 5 feet to the lagoon surface. At Takamaka there is a spring of fresh water, and a grove of large *Calophyllum* and *Ficus* trees. This spring, with three others, all lying between Takamaka and the lagoon, is the only constant source of fresh water on the islands. The section finishes at Abbot's Creek, which is a narrow passage from the lagoon with a thick undergrowth of man-

Aldabra Atoll. Scale about 6 miles to 1 inch.

groves on each side; its bed is rocky and covered with very fine white mud; at its termination in the land it passes between small cliffs, all much overhung and obviously breaking down.

In another section, which passes from Vert Island in the lagoon northward to the sea, the country is all, with the exception of the shore zone, of the Champignon type, Platin being entirely absent. There is a gradual slope from the lagoon, becoming steeper at the beginning of the shore zone. Right up to the latter salt water is often found in pits in the rock, fluctuating, apparently, with the lagoon tides. The cliffs on this north coast are 4 feet or 5 feet higher than those before described, and are always much overhanging. Caves penetrate far into their faces, large portions of which have at intervals fallen on to the reef; this fallen rock appears to become disintegrated quickly, as small pieces are uncommon, the action of the sea being assisted by boring animals (small Gephyreans, boring molluscs, &c.). As elsewhere round the coast, the rock shows its component corals in a way which leaves no doubt as to their being in the same position as previous to their elevation. On the reef here there are three or four distinct regions; close to the

cliff there is a small belt of bare rock, often worn into hollows containing 3 feet or 4 feet of water; then a large area, mainly of broken coral fragments covered with Lithothamnia, and edged outside with a small boulder zone; and outside this, again, buttresses with a few colonies of living corals in the channels. Such are the usual features of the fringing reef at Aldabra, the appearance in the Takamaka section being quite exceptional.

After the previous descriptions, it is possible to speak more generally of Aldabra. The cliffs, as stated, show their structure wonderfully clearly, except in the southern bight, where they are sloping and buttressed; they are much overhung, and are crumbling fast. The general variations in level across the land are similar; the highest point is near the sea, and there is a steady decrease in level to the lagoon.

As regards the nature of the land, all the northern portion of the atoll—Polymnie Island, Malabar Island, and the north-east part of Main Island—consists of Champignon. The south-east portion of Main Island is chiefly Platin. In the centre of the south of Main Island there is a wide shore zone, and then a belt of Champignon. To the east and west of this portion are large mounds (65 feet in height) near the shore. They are obviously wind dunes, the seaward slope being gradual with little vegetation, the landward very steep and covered with bush. Opposite each dune the cliffs have almost entirely vanished, a direct slope of sand leading up to the dune. It is noticeable that in Aldabra, as in most of the other islands of this part of the ocean, dunes are only formed on the coast facing the strong south-east trades. The west portion of Main Island is chiefly Champignon. At Couroupa there is a dip in the rock which appears to extend from the shore right across to the mangrove swamp; it is filled with sand, and attains a maximum depth of 8 feet.

A portion of Picard Island and Esprit Island (in the lagoon) demand a fuller description.

Esprit is largely swamp, but round the south and west there is a ridge of rock about 30 feet high, which is obviously not typical coral rock. The majority of the ridge is composed of a dark brown hard rock; at the lower levels it is very solid and homogeneous, but higher up it takes the form of a coarse conglomerate or pudding stone. The top of the ridge is capped with a rock which appears extraordinarily like flint. On each side are pinnacles of a rock which is evidently composed very largely of a deposit of mollusc shells, and which has suffered excessive denudation. On the outer (lagoon) side of the ridge these pinnacles are only a few feet high, but on the inner side, towards the centre of the island, they form a series of grotesque up-standing pillars and walls, varying up to 15 feet in height; they appear to be standing on the brown rock.

Picard Island, which is mainly of typical coral rock, has in the centre (S.W.) a large plain of Platin country, on the east side of which is a large basin in the rock, in subterranean connection with the lagoon. On the floor of the basin I found several small pieces of the dark homogeneous rock, and, at one side, much of the brown conglomerate. The majority of the rock round the basin appeared purely calcareous, but there were some short veins (six inches to a foot wide) and masses of highly crystalline rock, some apparently calcite and some also

containing much phosphoric acid and apparently apatite. Bones, the teeth of elasmobranchs, and remains of other organisms, at present unidentified, were found both in the calcareous rock and in the brown 'conglomerate.' A small area near the basin was covered with pinnacles of the 'shell rock' as at Esprit.

Specimens of these rocks were sent home in advance, and some were sectioned and reported on as 'volcanic glasses' in the issue of 'Nature' of May 13, 1909.

There is little doubt but that this identification is entirely erroneous, for since my arrival I have myself examined them briefly, and find that almost all of these strange rocks, with the exception of the 'shell rock,' are largely composed of calcium phosphate, the colouring being apparently due to a considerable percentage of iron.

Arrangements are being made for the proper examination of these rocks, the formation of which is at present shrouded in mystery, but which, it is hoped, will eventually throw considerable light on the early history of Aldabra.

The four passes into the lagoon are interesting, and perhaps give a clue to its formation. They have usually deep central channels, with reefs on either side. Small rock islets are present on these reefs, and it appears certain from their existence that the passes are steadily increasing in size, and that their reefs are really the remains of the land kept up to low-tide level by growing coral. Live coral extends for some distance into the lagoon, there being in all cases a luxuriant bed just inside the pass. At the mouth of the pass all corals are largely encrusted with Lithothamnia, and further seawards many are completely killed by these algæ.

Besides the existing passes, it should be noted that there seems a likelihood of at least three more being formed—at Camp Frigate the mangrove swamp extends right through the island to the sea, and no doubt a certain amount of water already traverses the land at that point. In Polymnie Island, at one place the swamp is within 100 yards of the shore, and a pass will probably be formed in time; at Dune Jean Louis there is only a quarter of a mile between the sea and the swamp, and if the lagoon erosion continues, no doubt Main Island will be divided at this point. It is worthy of note that fresh passes seem always to be formed by lagoon erosion, and not from the seaward side.

The lagoon itself is very shallow, and the bottom sandy in the middle, changing into fine mud as it approaches the mangrove swamp. Everywhere one is forcibly struck by the extent of the erosion in the lagoon. Judging by its maze of small islands and mushroom-shaped rocks, at least one-third, or even more, of the lagoon can be shown to have been land at one time. At spring tides the amount of fine mud carried out to sea in suspension is very large, and it is obvious that the lagoon is still growing in size. There is some difficulty in accounting for the rapid transformation of the rock into mud, as boring animals are not common.

As regards the vegetation, it is impossible to say much until the specimens collected have been worked out. The mangrove swamps extend right round the lagoon sides of the islands, *Rhizophora* and *Brugiera* being the predominating genera, though there is also a large quantity of *Ceriops*. *Rhizophora* seems to require a deep mud, but

Brugiera thrives better in the more rocky places and on the small islands. In the extreme east of the atoll there is a large forest of the pseudo-mangrove *Avicennia*. The only other fact that need be mentioned is that Esprit Island has several plants not found elsewhere, or which are common to it and Picard Island alone.

The fauna also must be left until the collections arrive and have been examined. So far as can be seen at present, it appears to be of the regular coral-island type, with such additions in the land animals as would be natural considering the large amount of land and the larger flora. It should, however, be remarked that the mangrove swamps were very disappointing in their fauna, a condition very different from that described in mangrove swamps in other localities.

Large numbers of giant land tortoises still exist, but the problem of their distribution does not relate to Aldabra alone, as I have found their remains on Assumption and Cosmoledo, and they are also known to have occurred in nearly all the Seychelles Islands, two of which—Bird and Dennis—are coralline in structure.

In conclusion, I would suggest that the reefs and islands of the Aldabra-Farquhar line present a most interesting series representing the possible life of an atoll.

(*a*) *Astove.*—Land rim of atoll almost perfect and mostly rocky. Only one small pass of recent date. Lagoon exceedingly shallow, but getting rapidly deeper. Formation of another pass proceeding.

(*b*) *Aldabra.*—Land rim still very perfect, and mostly rocky. Several passes already in existence. Strong evidence of increase of lagoon at expense of land. Lagoon deeper, and at least three passes in course of formation.

(*c*) *Cosmoledo.*—Land rim broken up into a series of small islands only. Most of encircling reef bare, but evidence of a former rock-cap in mushroom-shaped rocks and minute islands. A noticeable increase of sand on the island, and decrease of rock. Lagoon deeper than that of Aldabra, and more open.

(*d*) *Farquhar.*—Judging from Mr. Stanley Gardiner's description, land rim very small. Island nearly all sand, and typical coral rock very scarce. Lagoon still more open.

(*e*) A final or hypothetical stage may be imagined as an atoll with a considerable lagoon, without, perhaps, any land; or, if land is present, only as sand cays piled up on the reef.

The Amount of Gold Coinage in Circulation in the United Kingdom.—Interim Report of the Committee, consisting of Sir R. H. INGLIS PALGRAVE (*Chairman*), Mr. H. STANLEY JEVONS (*Secretary*), *and* Messrs. A. L. BOWLEY *and* D. H. MACGREGOR.

AT a meeting of the Committee held in November 1908 the estimate of the total gold coinage in circulation obtained from the available data was considered, and it was decided that the only assignable limits of

error were so great as to make the estimate of little value and unfit for publication. It was decided to attempt an estimate on the basis of the gold of dates 1904-6 in circulation, and for the purpose of calculating this to obtain a fuller knowledge of the composition by date of British gold coin exported. By the kindness of the Governor of the Bank of England five bags of gold coin destined for export were opened in February, 1909, and the coins of different dates counted. The result shows an unexpected variety in different bags, and they can hardly be taken as a true sample of the whole coinage exported. An estimate of the exports based on the composition of these bags gives a figure for the total coinage differing very widely from the previous estimate.

Agricultural Development in the North-West of Canada, 1905 *until* 1909. *By* Professor James Mavor.

[Ordered by the General Committee to be printed *in extenso*.]

In the end of the year 1903 the then President of the Board of Trade, the Right Hon. Gerald Balfour, did me the honour of asking me to make a confidential report upon Agricultural Production in the North-West of Canada, with special reference to the production of wheat for export. This report, which was the result of study of the subject since 1896, was prepared in 1904, the narrative and statistical portions being brought down to December 31 of that year. The report was published in 1905.[1] The Chairman of the Sub-section of Agriculture of the British Association has invited me to contribute a paper bringing down the data to the present time.

The region which was the subject of inquiry consisted of the province of Manitoba and the territories of Alberta, Assiniboia, and Saskatchewan. It comprised in effect the great plains from the Red River valley to the Rocky Mountains and from the international boundary to the valley of the North Saskatchewan. In September 1905 the political structure of the region was altered. The area of the territories above mentioned, together with additional areas towards the north, was divided into two provinces—Saskatchewan and Alberta. The Legislatures of these new provinces were endowed with the same powers as those of the other provinces of the Dominion, excepting that the control of the unalienated public lands and the control of the North-West Mounted Police were retained in the hands of the Dominion authorities. Regina was selected as the capital of Saskatchewan, and Edmonton of Alberta. Some time elapsed before the various departments of the new Governments were fully organised. New statistical districts had to be determined in the two new provinces, and thus comparison of their data with those of the former districts came to be somewhat difficult. The

[1] *Report to the Board of Trade on the North-West of Canada, with special reference to Wheat Production for Export*, by James Mavor, Professor of Political Economy in the University of Toronto, Canada, 1904 (Parliamentary Paper) (Cd. 2628), London (1905).

erection of the new provinces was coincident with a considerable increase in immigration, largely from Great Britain and the United States, although the population was also considerably increased by a less readily estimated immigration from the province of Ontario.

In the preparation of the report of 1904 I found myself confronted by the fact that the region in question had only been partially surveyed, and that no agricultural survey properly so called had been made of any portion of it. Estimates of the agricultural possibilities of the region were thus matters not of knowledge but of opinion; and opinions of different persons, many of them equally well qualified to form judgments on such questions, varied very widely. In these circumstances it was necessary to be guarded in the formation of any conclusions about the conditions of the time and still more about the possibilities of the future. I felt bound, however, to consider and present such estimates of these possibilities as had been brought to my notice. At the same time I explicitly refrained from offering endorsement of any of these estimates. On the grounds of what official data were at the time available concerning the agricultural history and apparent tendencies of the agricultural exploitation of the region, I ventured to suggest some provisional conclusions of a very general character. Among these conclusions was the following:—

'Very great improvements in the productive power of the country and a very considerable increase in the effective population, as well as a more exclusive regard to wheat cultivation, would have to take place before the North-West could be regarded as being in a position to be relied upon to produce for export to Great Britain a quantity of wheat even nearly sufficient for the growing requirements of that country. That an exclusive regard to wheat cultivation is unlikely to arise seems certain from much of the foregoing detail. Even if the soil were uniformly suitable, and even if the seasons could be absolutely relied upon, the disposition of the people and their settlement upon small farms of which the owner is also the cultivator seem against the exclusive cultivation of one crop. The tendency of knowledge derived from experience and of instruction and advice derived from the experimental farms, as well as other Governmental encouragement of mixed farming, are all opposed to exclusive cultivation of wheat or of any other one crop, as is also the experience of the States immediately to the south of the international boundary.' [1]

The experience of the past five years very strongly confirms this conclusion. A considerable improvement in the productive powers of the country has taken place, a considerable increase in the effective population has occurred, yet the quantity of wheat produced is still far short of the quantity annually imported by Great Britain. Moreover there has been during these years less rather than more proportional cultivation of wheat. Mixed farming has become more common. These facts appear in the statistics which follow.

[1] *Report to the Board of Trade on the North-West of Canada, with special reference to Wheat Production for Export*, by James Mavor, Professor of Political Economy in the University of Toronto, Canada, 1904 (Parliamentary Paper) (Cd. 2628), London (1905), p. 114.

The Area of the Prairie Provinces.—The area of the three prairie provinces—Manitoba, Saskatchewan, and Alberta—is much larger than the area of the region formerly occupied by Manitoba and the North-West Territories. This appears in the following table:—

—	1904 In Millions of Acres			1905		
	Land	Water	Total	Land	Water	Total
Province of Manitoba . . .	41·2	6·0	47·2	41·2	6·0	47·2
The Territories, afterwards the Provinces of Saskatchewan and Alberta (including the added areas)	187·9	3·0	191·0	155·1 160·8	5·3 1·5	160·4 162·3
	229·1	9·0	238·2	357·1	12·8	369·9

The added areas thus amounted to more than fifty per cent. of the original area of the region. The addition consisted of almost the whole of the former territory of Athabasca. The greater part of this addition is beyond the region of practicable settlement for commercial production at the present time.

Meteorological Data of the Years 1905-09.—Attention was drawn on the previous occasion to the fact that the observation stations of the Meteorological service do not furnish records for a sufficient length of time to enable decisive conclusions to be formulated regarding the important questions of temperature and precipitation. It is hardly necessary to lay emphasis upon the well-established scientific fact that the occupation of a country does not influence the climate. The erection of buildings and the planting of trees may affect, within certain narrow limits, the currents of air on the immediate surface, and cultivation may render the soil less impervious to moisture, and may thus alter the quantity of moisture held by the soil; but none of these changes has any influence upon the rainfall or upon other phenomena of a cosmic character. This, at all events, is the general conclusion of meteorologists, who alone are entitled to be heard upon such a question.

Average Daily Maximum Temperature.

—		April	July	Sept.	Nov.	January
25 years' observations	Calgary .	53·2	74·7	63·7	35·3	23·1
	Edmonton .	52·9	73·7	62·1	39·5	16·2
	Winnipeg .	50·1	77·6	65·8	30·5	8·0
20 years' observations	Medicine Hat	44·6	68·1	56·1	28·4	11·8

Normal Precipitation.

The following table shows the average annual precipitation observed at the stations named:[1]

1888–1907.

	Inches		Inches
Calgary (20 years' observation) .	16·30	Qu'Appelle (20 years' observations)	18·84
Medicine Hat " .	13·11	Mimiedosa " .	17·36
Edmonton " .	18 20	Winnipeg " .	20·81
Battleford " .	13·79	Macleod (14 years' observations)	13·15
Prince Albert " .	16·60	Brandon " .	17·38
Swift Current " .	15·90		

Table showing Dates of First Occurrence of Sowing, Hay-cutting, and Grain-cutting in the North-West in Successive Years since 1905.

—	Sowing	Hay-cutting	Grain-cutting
1905			
Alberta . .	—	July 20	First week in August at Edmonton
Saskatchewan	—	—	July 25
Manitoba .	—	—	First week in August
1906			
Alberta . .	90 per cent. of wheat in by the end of April. Oats sown in first week of May	July 12	Wheat-cutting general by middle of August. Barley 4th. Oats 13th
Manitoba .	Wheat-sowing on April 30. Oat-sowing finished April 30. Barley later	—	August 4
1907			
Alberta . . Saskatchewan Manitoba .	Seeding finished about May 31	—	Harvest began generally on September 5, except in far northern Alberta, where no crops ripened
1908			
Alberta . . Saskatchewan. Manitoba .	Wheat and oats 2 in. to 3 in. high by May 31	Haying completed July 24	Wheat-cutting middle of August

General Calendar of the Seasons.

—	Manitoba	Saskatchewan	Alberta
1905	Good year. Large yield	Good year. Large yield. 'Stinking smut prevalent'	Dry spring in west and north centre of province. Rains in June, with two frosts. Harvest weather good
1906	Large crop, but deficient average yield reported	Early season. Hot winds in July. Grain prematurely ripened. Yield per acre reported less than 1905	Winter mild. Light snowfall. Heavy rains in May. Dry and warm in June and July. Hot and dry in August

[1] I am indebted to Mr. R. F. Stupart, Director of the Dominion Meteorological Department, for compiling these statistics.

General Calendar of the Seasons—continued.

—	Manitoba	Saskatchewan	Alberta
1907	Unfavourable year. Deficient harvest	Unfavourable year. Deficient harvest. Reported yield 13·52 bushels per acre	Unfavourable year. Deficient harvest
	Government Loan of Seed.		
1908	Favourable spring	Favourable spring	Favourable spring
	Hot and dry in July in three provinces		
	Good yield and heavy crop		
1909	Low temperature and cold rains early in June, followed by dry weather. Seeding in all provinces was late. In the end of June some heavy local rains. Conditions of crops irregular and difficult to estimate in the aggregate. Hot and dry weather in July and August led to early harvesting. Result of crop cannot as yet be stated with confidence		

Population.—The last Dominion Decennial Census having been taken in 1901, it was thought that an intermediate census ought to be taken of the three prairie provinces in 1906, partly because of the considerable immigration and partly because of the readjustment of the political status of the population.

The following table shows the general result of this census, which was taken as at June 24, 1906:—

—	1901	1906	Increase
			%
Manitoba	255,211	365,688	43·28
Saskatchewan	91,279	166,484	182·39
Alberta	73,022	112,390	153·91
Total	419,512	808,863	92·81

The following table shows the origin of this population in a very general way:—

—	Per cent. 1901	Per cent. 1906
Born within the British Empire	78·40	70·21
Born within the United States	4·95	11·22
Total British and American born	83·35	81·43
Born in other countries	16·65	18·57
	100·00	100·00

The available statistics show that although the immigration from the United States had been considerable, there were, in 1906, in the three provinces but 90,738 persons who had been born in the United States. The population of British origin was thus still largely preponderant.

In the report of 1904 attention was drawn to the greater increase of the urban than of the rural population, as shown by the census returns up till 1901. This increase has gone on to an even greater extent than formerly, as is shown by the following table:—

—	1901		1906	
	Rural Population	Urban Population	Rural Population	Urban Population
Manitoba	72·41	27·59	62·24	37·76
Saskatchewan	84·38	15·62	81·20	18·80
Alberta	74·00	26·00	68·71	31·29
	75·28	24·72	69·77	30·23

The relation between the increase of cultivation and the growth of the population is shown by the following table. The figures are for the three prairie provinces combined.

—	1901	1906
Rural persons	315,821	564,278
Urban ,,	103,691	244,585
Total	419,512	808,863
Number of acres cultivated in field crops	3,597,691	8,040,980
Number of acres cultivated in field crops per 1,000 rural inhabitants	11,391	14,250
Number of acres cultivated in field crops per 1,000 of all inhabitants	8,576	9,941
Number of acres cultivated in wheat per 1,000 of all inhabitants	5,950	6,258

It will thus be seen that, together with the increase of population, there has occurred an increase of cultivated area per head of the population. While in 1901 the cultivated area amounted to less than 8·6 acres per head, of which 5·9 were in wheat, or 68 per cent., in 1906 the cultivated area was 9·9 acres per head, of which 6·3 acres were in wheat, or 62 per cent.

Immigration.—The difficulty of collecting and of presenting accurate statistics of immigration and emigration for Canada was noticed in the report of 1904. The chief reason for this difficulty is that the large traffic between the United States and Canada by rail and steamer and the considerable traffic by road or by prairie cannot readily be divided into migratory traffic properly so called and tourist or commercial traffic. Moreover even if such a distinction could be made the actual numbers passing, excepting those travelling by ordinary means of conveyance, could not be accurately ascertained. Large numbers of settlers, for example, have in past years crossed from the United States into Canada in their own covered wagons at unobserved points on the frontier. Methods other than those involving actual count on the frontier lead inevitably to omissions and duplications. Insufficient attention has also been paid to the deductions from the

totals of immigrants in respect to emigration. This has, however, been undoubtedly a smaller element than it was ten years ago.

According to the statistics of the Department of the Interior, which, for the reasons explained above, must be accepted with qualifications, the following is a comparative statement of the immigration into Canada during the years since 1900.

Comparative Statement of Arrivals at Inland and Ocean Ports during the Four Years ending March 31, 1908.

—	Great Britain and Ireland	United States	Other Countries	Total
1904–05	65,359	43,632	37,255	146,266
1905–06	86,796	57,919	44,349	189,064
1906–07 (9 months only).	55,791	34,659	37,217	124,667
1907–08	120,182	58,312	83,975	262,469

The total number of arrivals during the period of six years from 1901 till 1906, embracing the two census years 1901 and 1906, was as follows:—

	United Kingdom	United States	Other Countries	Total
1901–06 . .	273,390	240,590	196,572	710,552

It will be observed that during recent years there has been a considerable increase in the immigration from all the sources indicated, but especially from the United Kingdom and from other European countries. Large as the immigration from the United States has been it has not been so great proportionally as that from other countries.

The reasons for the increased emigration from the United Kingdom have been chiefly the following: the increase of population; the decline of trade, due largely to American fluctuations; the disturbance of the labour and money markets, due to the South African war; the activity of emigration societies, emigration agents, and steamship companies; and the offer of free homestead land in the Canadian North-West. Excepting the first—viz., the increase of population—these conditions are all temporary. The agricultural population of Great Britain comprises now so small a proportion of the total that agricultural wages have risen sharply, and it must thus become more difficult to induce the agricultural labourer to change his habitat. It must be realised that although during the past two or three seasons many former tenant farmers and other persons with capital have emigrated and have established themselves in Canada, this class of men is not accustomed to hard physical labour personally. They have been employers and directors of labour. In that country labour is difficult to obtain, and very expensive when it is obtained. So long as the free homesteads are offered, and so long as mining and prospecting offer high remuneration, the farmer who attempts to cultivate his land by the labour of others must be seriously handicapped, in spite of its fertility.

Gradual Depletion of the Unalienated Public Lands.—An excellent map recently issued by the Department of the Interior shows that the area of land available for homestead entry south of the North Saskatchewan River is now comparatively small. The only district in

which there is any considerable area still available is the large irregular triangle of which the main line of the Canadian Pacific Railway between Swift Current and Medicine Hat may be taken as the base, the apex being on the line of the new Grand Trunk Pacific Railway near the Buffalo Park Reserve. This region has always been looked upon with some disfavour as a field for settlement; but some part of it will doubtless turn out to be of value.

Otherwise the intending homesteader will have to find his way northwards. This, of course, does not mean that the whole of the area of the southern part of the three provinces is settled. Very large areas are in the hands of the railway companies; other areas are in the hands of land and colonisation companies, and a considerable amount is held by farmers and others for speculative purposes.

If immigration were increasing greatly in the immediately succeeding years there would undoubtedly arise a land question, owing to the difficulty of procuring land at a moderate price.

The condition of trade in Canada in 1907 and the deficient wheat crop of that year rendered it difficult for the country to absorb so great a number of fresh arrivals, most of them bringing very slender resources to enable them to establish themselves. Many crowded into the towns during the winter of 1907-8, and some were the recipients of charitable relief. Such conditions led to legislation increasing the severity of the immigration law and compelling the steamship companies to take back to the port of shipment persons who, being found to be unable to support themselves, or being otherwise 'undesirable immigrants,' were ordered to be deported. This legislation had the effect of diminishing the efforts of the steamship agents and the other agencies engaged in the immigration business to increase the immigration by mere numbers. The question of quality of immigrants is very intricate and cannot be said to be settled by the methods prescribed by the recent legislation on the subject.

In 1907-8 there was a considerable increase in immigration, the number of immigrants in that year being the largest in the history of the country.

The Policy of Wide Distribution of Immigrants.—The question of distribution of immigrants is one which is not wholly within the control of the Government in a free country. Many settlers resent the interference of the Government in determining where they should settle. Accusations of political instead of purely administrative motives determining action in particular cases would be quite certain to arise. When individual settlers come into a new country they must thus be left a large range of choice in the available field. Nevertheless the Department of the Interior does in practice reserve certain areas from homestead entry, and does from time to time throw these areas open to the settler. The policy of land settlement is thus to a certain extent under the control of the Department. The problem may be put in this way: Is it wiser to concentrate the incoming tide of immigration in particular areas, or ought it to be permitted to go where it will? If it is concentrated, the favoured areas increase rapidly and regularly in value, as the incoming immigration produces additional demand for land within the areas. If immigration is dispersed, the exercise of administration and provision of the means of communication must accompany or follow the dispersal, and the eccentricity of a few settlers

who might wish to be very remote from others may lead the country into extremely heavy expenses for railways, roads, education, police, &c.

For example, some Scottish settlers who had placed themselves by singular choice over one hundred miles from a railway station had to be visited during the winters of 1907 and 1908 by a troop of Mounted Police, to whom the severe journey was an arduous and costly affair. The provision of Governmental administration for isolated groups is thus very expensive, and for that reason sometimes very inadequate. The disadvantages of isolated and sparse settlement are felt most acutely in respect to education. Although the farmers appear to desire that their children should be educated there are great tracts in which there is no provision at all, and other great tracts in which the provision is very slender.

For these reasons the recent settlements to the north of Prince Albert and those in the Peace River District seem to be quite premature. They are produced by a mere *furore* for change. Most of the farmers who have gone to the regions remote from markets and remote from civilisation have sold their farms in Manitoba, and even in Ontario, and have gone to the remote regions because they believed the optimistic tales of the persons who had visited the district in a casual way. The authoritative opinion of agricultural experts is altogether against the settlement of the Peace River District under present conditions, yet remoteness has a great charm for some people.

The administrative expenses of a widely scattered population must be disproportionately heavy, no matter how the real incidence of the cost may be concealed by indirect taxation and by the system of provincial subsidies. The cost of roads has only been prevented from becoming an intolerable burden by mere neglect of them. As the road allowances come to be defined, and as the traffic upon them increases, either the roads must continue to be neglected, to the great loss of the inhabitants, or they must be kept in repair at an enormous cost.

Collection of Agricultural Statistics.

It is not necessary to urge the importance of the collection of reliable agricultural statistics, but it seems to be advisable to remark that their collection in Canada is not in a very satisfactory condition at present.

In 1908 the duties of the recently established permanent Census and Statistical Office at Ottawa were enlarged, and this office was entrusted with the collection of agricultural statistics throughout the Dominion. This measure did not, however, result in the abrogation of the functions of the provincial statistical officers. We are thus periodically presented with two sets of statistics for the same areas, one set collected and compiled by the Dominion Statistical Department and another set collected and compiled by the provincial authorities. The methods adopted in the collection and compilation are not the same, and the statistics present very grave discrepancies. For example, the estimate of the Dominion Statistical Office for the wheat crop of 1908 is 91,853,000 bushels, while the combined estimates of the three prairie provinces is 107,002,093 bushels, a difference

of about 16 per cent. Since the latter figure is that adopted by the Dominion Department of Trade and Commerce, the result is very confusing. A similar disparity is observable in respect to the oat crop; the Dominion Statistical Office estimates it for 1908 at 96,718,000 bushels, while the provincial authorities place it at 109,013,812 bushels. The statements of the acreage under crop exhibit similar discrepancies. It is quite impossible for an independent inquirer to decide between these rival authorities. The region is so vast and, so far as the greater part of it is concerned, so sparsely populated that the collection of information from every individual farmer is a difficult and expensive process. An attempt is, however, being made by the Dominion Statistical Department to collect the data in this way. On the other hand the Saskatchewan Department of Agriculture has adopted the method of obtaining from the 'threshers' a statement of the quantities of grain threshed by them. Of these 'threshers' about 2,400 made returns. The acreage under crop is estimated from returns made by 15,000 individual farmers. In 1906 there were, however, about 56,000 individual farmers, so that unless the farms from which returns were obtained were of carefully selected types, and unless the total number of each type was known with fair precision, it is obvious that there is room for errors of magnitude.

It appears in the first place that a greater number of expert statistical officers might be employed, and in the second place that an adequate agricultural survey of the whole region might be undertaken at an early date and carried forward gradually to completion. The collection and continuation of agricultural statistics is a special business which has been highly developed elsewhere, and the time has undoubtedly arrived when the results of the best experience should be applied to Canada. The surveys which have been and are being made by the Dominion land surveyors, under the direction of the Topographical Surveys Branch of the Department of the Interior, are of value so far as they go, although many of them are now out of date; and moreover the reports of the land surveyors describe the land as it was before settlement. What is wanted is a survey of settled as well as of unsettled lands, with a record of their agricultural history and present condition. Such a survey seems to be an indispensable preliminary to the annual collection of sound agricultural statistics. Until such a survey is made it is really quite impossible to arrive at any but more or less fanciful conclusions about the future productivity of so vast and varied a country.

None of the statistics give any statement of the number of acres sown to wheat of which no crop has been reaped, nor of the quantity of wheat which has not ripened, nor of the quantity which has been frozen, or damaged by smut or otherwise. Without these particulars an accurate knowledge of the yield in relation to the quantity sown cannot be obtained; and the fertility of the soil is obscured, as well as, in some cases, the extent to which it is being injuriously exploited.

Agricultural Production, 1906-07.—In stating the agricultural production of the past four years it is necessary, for the reason explained above, to give the results both of the Dominion and of the provincial authorities. This has therefore been done in the following table, which has been compiled from the reports of the respective departments.

Statistics of the Production of Field Crops in the North-West of Canada, 1905-1909.

(1) *Provincial Statistics.* *Acreage in Millions of Acres.*

—	1905				1906				1907				1908				1909			
	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total
Wheat . .	2·64	1·13	0·10	3·88	3·14	1·73	0·18	5 05	2·79	1·97	0·21	4·97	2·85	3·70	0·32	6·87	2·85	4·09	0·4	7·34
Oats . .	1·03	0·45	0·24	1·72	1·16	0·63	0·33	2·13	1·21	0·74	0·31	2·26	1·21	1·77	0·43	3·41	1·21	2·24	0·8	4·25
Barley . .	0·43	0·03	0·06	0·53	0·47	0·05	0·07	0·60	0·65	0·08	0·05	0·78	0·57	0·23	0·08	0·88	0·66	0·24	0·2	1·10
Other grains	0·04	0·03	0·001	0·07	0·03	0·08	0·01	0·11	0·03	0 13	0·01	0·17	0·08	0·26	0 01	0·35	0·07	0·32	0·01	0·40
Total .	4·15	1·64	0·42	6·20	4·80	2·50	0·59	7·89	4·68	2 92	0·58	8·18	4·71	5·96	0·84	11·51	4·79	6·89	1·41	13·09

Yield in Millions of Bushels.

—	1905				1906				1907				1908				1909			
	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total
Wheat . .	55·8	26·1	2·3	84·18	61·3	37·0	4·0	102·3	39·7	27·7	4·2	71·57	49·3	50·7	7·1	107·00	49 25	90·22	Statistics not yet available	
Oats . .	45·5	19·2	9·5	74·21	50·7	24·0	13·1	87·80	42·1	23·3	9·2	74·71	44·7	48·4	15·9	109·01	44·69	105·47		
Barley . .	14·1	0·9	1·8	16·73	17·5	1·3	2·2	21·01	16·8	1·4	1·1	19·30	18·1	4·0	1·9	24·00	18·14	7·83		
Other grains	0·6	0·4	0·01	0·96	0·7	0·7	0·07	1·48	0·3	1·4	0·1	1·86	0·4	2·6	0·1	3·11	0·98	4·45		

(2) *Dominion Statistics.* *Acreage in Millions of Acres.*

—	1905				1906				1907				1908				1909			
	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total
Wheat .	2·42	1·37	0·15	3·94	2·72	2·1	0·20	5·06	2·8	2·04	0·22	5·06	3·0	2·39	0·27	5·66	2·80	3·69	0·39	6·88
Oats . .	0·78	0·61	0·31	1·70	0·93	0·9	0·50	2·32	1·2	0·80	0·48	2·48	1·3	0·93	0·52	2·77	1·39	1·85	0·82	4·06
Barley .	0·25	0·04	0·08	0·37	0·34	0·07	0·10	0·52	0·6	0·08	0·11	0·79	0·7	0·08	0·13	0·91	0·70	0·14	0·19	1·02
Other grains	0·01	0·04	0·005	0·06	0·02	0·1	0·01	0·15	0·01	0·003	0·001	0·01	0·01	0·003	0·01	0·02	0·03	0·11	0·01	0·15
Total .	3·46	2·06	0·55	6·07	4·01	3·21	0·81	8·05	4·6	2·92	0·81	8·34	5·01	3·41	0·92	9·36	4·92	5·79	1·41	12·11

Yield in Millions of Bushels.

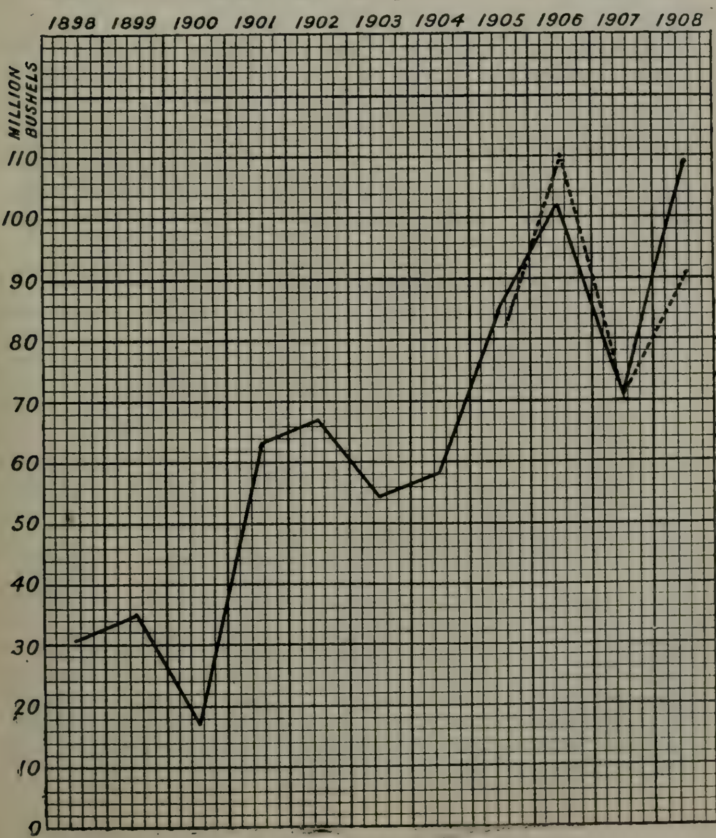
—	1905				1906				1907				1908				1909			
	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total	Man.	Sask.	Alb.	Total
Wheat .	47·6	31·8	3·0	82·46	54·5	50·2	5·9	110·59	39·7	27·7	4·2	71·57	50·3	34·7	6·8	91·85	52·70	85·20	9·60	147·50
Oats . .	31·5	25·6	11·7	68·81	44·6	41·9	24·0	110·57	42·1	23·3	9·3	74·71	44·7	29·2	22·8	96·72	55·27	91·80	38·38	185·45
Barley .	7·5	1·2	2·2	10·97	12·0	2·8	3·9	18·68	16·8	1·4	1·1	19·18	17·1	2·0	3·9	22·93	20·87	4·50	6·00	31·37
Other grains	0·2	0·5	0·1	0·77	0·3	1·6	0·3	2·20	0·4	1·4	0·01	1·81	0·4	1·2	0·3	1·90	0·39	1·82	0·26	2·47

Wheat.—The yield of wheat in bushels per acre for the area occupied by the three prairie provinces can be shown collectively only since 1898. Since then it has fluctuated widely—from 9·11 bushels in 1900 to 25·16 in 1901. During the past six years it has been twice above 20 bushels and four times below 16 bushels. The period is much too short for decisive conclusions, but there is no justification in the history of crops in the North-West for the custom of multiplying the estimated acreages by the arbitrary figure of 20 bushels and arriving in this way at a haphazard estimate of the crop.

The following diagram exhibits the yield of wheat in the area occupied by the three prairie provinces from 1898 to 1908. The statistics upon which the diagram is based are those of the provincial and of the Dominion authorities, shown separately since the series of the latter authority began.

Diagram showing the Yield of Wheat in Manitoba and the North-West Territories from 1898 *till* 1904, *and in Manitoba and the Provinces of Saskatchewan and Alberta,* 1905 *till* 1908.

[Aggregate Statistics of Bulletins of respective Provinces—Solid Line
Statistics of the Census and Statistical Department, Ottawa—Broken Line.]



Cost of Producing Wheat.—In my report of 1904 I gave some details of the cost of wheat-production. The first of the following schedules applies to the region, lately settled by farmers from the United States, which lies round Ponoka, on the Calgary and Edmonton line. The district is more suitable for the production of oats than of wheat; but labour, as a rule, is not so difficult to obtain as in many other districts. The date of the costs is March 12,1907. Two other schedules of cost, dated 1909, one in the Weyburn District and the other in the Rouban District, are given for purpose of comparison. The costs were exact at the time they were compiled; but I do not suggest that they should be regarded as applicable generally, or even over a wide area.

—	At Ponoka 1907			
	New Land		Old Land	
	Per Acre	Per Bushel (at 20 per Acre)	Per Acre	Per Bushel (at 20 per Acre)
Breaking	$ 3.00	$ 0·1500	—	—
Cultivation	4.05	0·2025	$ 2.80	$ 0·1400
Seed (1½ bushel)	1,50	0·0750	1.50	0·0750
Harvesting, threshing, &c. . .	2.68	0·1340	2.68	0·1340
Hail insurance	0.15	0·0075	0.15	0·0075
Cost at farm	$ 11.38	$ ·5690	$ 7.13	$ ·3565
Hauling to elevator or station .	0·90	·0450	0.90	0·0450
Cost at elevator or station . .	12.28	$ 0·6135	$ 8.03	$ ·4015
Price, March 11, 1907 . . .	—	0·5300	—	0·5300
Loss on new land	—	$ 0·0835	Gain on old land	$ 0·1285

Three items not included here: (1) taxation; (2) value of farmer's superintendence; (3) rent or interest on capital.

—	In Weyburn District 1909			
	New Land		Old Land	
	Per Acre	Per Bushel (at 20 per Acre)	Per Acre	Per Bushel (at 20 per Acre)
Breaking	$ 3.25	$ 0·1625	—	—
Cultivation	1.90	0·0950	$ 2.40	$ 0·1200
Seed	1.50	0·0750	1.50	0·0750
Harvesting, threshing, &c. . .	2.75	0·1375	2.75	0·1375
Cost at farm	$ 9.40	0·4700	$ 8.65	0·3325
Hauling to elevator	1.00	0·0500	1.00	0·0500
Cost at elevator	10.40	0·5200	$ 9.65	$ 0·3825
Freight to Port Arthur	—	0·1200	—	0·1200
Cost at Port Arthur	—	$ 0·6400	—	$ 0·5025

—	In Rouban District 1909			
	New Land		Old Land	
	Per Acre	Per Bushel (at 30 per Acre)	Per Acre	Per Bushel (at 30 per Acre)
Breaking	$4.50	$0·1500	—	—
Cultivation	3.50	0·1167	$2.60	$0·0867
Seed	1.40	0·0433	1.40	0·0433
Harvesting, &c.	3.75	0·1250	3.75	0·1250
Cost at farm	13.15	0·4350	$7.75	0 2550
Hauling grain	1.50	0·0500	1.50	0·0500
Cost at elevator	14.65	0 4850	9.25	0·3050
Freight to Port Arthur . . .	—	0·1200	—	0·1200
—	—	$0·6050	—	$0·1250

It is to be observed that, with the exception of seed and binder twine the whole of the above costs are costs for labour, which on a small acreage the farmer may, with his family, render himself. His actual outgoings are thus small; but if he is a new comer, working on new land, he has to compete with others whose land has already been in cultivation for years, and whose net earnings are therefore much greater, whether they employ labour or not.

The costs above enumerated vary with the district and with the season, so also does the net price obtained, and therefore the profit. Any attempt to strike an average must therefore result in an arbitrary figure which would be almost destitute of value. The above schedules are given chiefly with a view of suggesting how such costs might be made up. In addition to the enumerated items there are to be considered also three others, one of them variable in different districts, although easily ascertainable, viz., taxation; the others are very difficult to estimate. These are the value of the farmer's labour of superintendence — his physical labour has been provided for — and the amount of his rent or the interest upon the purchase price of his land, with depreciation or improvement taken into account. In the case of production upon new land the balance of the cost of cultivation over that of old land may fairly be spread over, say, five years. In this way the net mean annual cost of his wheat to the farmer in the cases quoted would be reduced. His net profit in any one year would, however, depend upon the proportion of new land which he brought into cultivation.

At a Winnipeg price of 75c. per bushel the farmer would probably make a gross profit, out of which the three last-mentioned items would have to be defrayed, of approximately 20c. per bushel, upon such of his wheat as might reach the standard for which this price was obtainable. Out of this gross profit the farmer has to provide his wages of superintendence, interest upon the amount paid for his land, interest upon his agricultural capital, and, besides, an insurance fund against the fluctuations of the seasons and the markets.

It should be observed that if the cost of the seed is deducted from the total costs, where the farmer saves his own seed, the quantity of the seed should be deducted from the yield.

Increased Miscellaneity of Agricultural Production.

The process which was noticed in the conclusion quoted above as having manifested itself during the years preceding 1904—viz., the increase in the miscellaneity of agricultural production—has been very conspicuous in the more recent period, as is shown by the following table.

Percentage of Acreage sown in Wheat to Total Acreage under Grain Crops.[1]

—	1905	1906	1907	1908	1909
Wheat . .	62·56	63·96	60 68	59·20	55·44
Other crops . .	37 44	36·04	39·32	40·80	44·56
	100·00	100·00	100 00	100·00	100·00

Reference to similar calculations in the report of 1904 will show that this decline in the proportion of wheat crop area to the total cultivated area has continued since 1900, with two slight retardations, one in 1903 and the other in 1906.[2]

It is to be observed that the crop which has shown the greatest proportional increase is oats. This is exhibited in the following table.

Percentage of each crop in relation to the Total Area under the following crops.

—	1905				1909			
	Man.	Sask.	Alta.	Total	Man.	Sask.	Alta.	Total
Wheat .	63·73	68 90	25·85	62 56	57·31	59·11	27·54	55 44
Oats .	24·86	27·43	58·38	27·79	28·37	33 12	58·66	33 57
Barley .	10·42	2·01	15 59	8·55	14·20	3·56	13·31	8·72
Flax .	0·60	1·54	0·14	0·82	—	4·21	—	2·17
Rye . .	0·17	—	—	0·11	0·10	—	0·49	0·09
Peas .	0·05	—	—	0·03	0·02	—	—	0·01
Speltz .	—	0·12	0·01	0 03	—	—	—	—
Corn .	0·17	—	—	0·11	—	—	—	—
	100 00	100·00	100·00	100·00	100·00	100 00	100·00	100·00

The increase in the absolute and in the proportional production of oats is due chiefly to the great amount of railway construction which has been going on in the three provinces during the past five years, and to a less degree to the immigration of new settlers. Both of these circumstances have involved greatly increased use of horses, and the relatively high prices obtainable for oats has constituted a strong inducement for the farmer to cultivate that crop. It will be observed

[1] The percentages are based upon the statistics of the Departments of Agriculture of the three prairie provinces respectively.

[2] Cf. Report, 1904, p. 57.

that in Alberta there is a slight increase in the proportional production of wheat. This has taken place almost entirely in the southern part of the province. Oats remain the preponderating crop in the north.

Agricultural Progress.—The condition of agricultural progress may be estimated from the statistics which have been given. There can be no doubt that, although summer fallowing is becoming more common, continuous cropping is still the rule. When wheat yields a high price it is very difficult for the farmer to realise that although he may be able to secure enough from two or three crops to pay for his farm he may in a few seasons exhaust its value. This method of continuous cropping has come to be known in the West as 'mining the farm.' Rotation of crops is, however, coming into practice, and mixed farming is becoming more common.

Summer Fallowing.—Although summer fallowing has been universally recommended by the directors of the Experimental Farms and other agricultural authorities it is as yet applied to a comparatively small proportion of the area under wheat cultivation. The last year for which statistics on this point are available is 1906. In this year the proportion of the total acreage in the three provinces under spring wheat which had been fallow the previous summer was only 25 per cent. Manitoba exhibited the highest proportion, or about 30 per cent.; Alberta the lowest—about 16 per cent.

Irrigation.—There are being carried out at present three large schemes—

1. The Alberta Land and Irrigation Company's, commonly known as the Galt Scheme.

2. The Southern Alberta Irrigation Scheme. It will probably be two years from the present time before this company is in a position to supply water. They expect to have about half a million acres under ditch. The land with which they are dealing is reported to be fine land, but useless without irrigation.

3. The Canadian Pacific Railway Scheme. This is by far the largest of all the schemes. The ultimate intention is to apply it to about 3,500,000 acres of land which formed the Canadian Pacific Railway grant in the semi-arid area. This land is in a solid block; the arrangement as to alternate sections which applied to the remaining 22,000,000 acres of their grants does not apply to this area. At present the scheme involves about 1,000,000 acres. The block embraced in this portion is divided into three sections—Eastern, Central, and Western. In the Western section there remain undisposed of about 250,000 acres. The following works are in progress and will be completed in 1909:—

Main canal, 17 miles.
Secondary canals, 289 miles.
Distributing ditches, 1,331 miles.

About $3,500,000 have already been expended. The total estimated expenditure for the three sections is $8,000,000. The plans for the irrigation of the eastern and central sections are now being made.

During the two past years the Canadian Pacific Railway Company has undertaken to prepare the land, fence it, and erect buildings, &c., for purchasers of land within the irrigation block in advance of actual

settlement, charging 5 per cent. over cost. The following represents the work done in this way:—

—	1908	1909
Breaking	4,000 acres	15,000 acres
Sown to wheat	2,000 ,,	8,000 ,,
Fence erected	36 miles	150 miles
Wells sunk	None	50

Some portion of the area, in addition to the quantity mentioned as being sown to wheat, is no doubt destined to be so employed next year.

The proportion of the work done by the Irrigation Department of the Canadian Pacific Railway in relation to the whole of the work done in the irrigation block is about 33 per cent.

The following gives the increase in the acreage under cultivation in the irrigation block since 1905:—

1905	1,600 acres	1908	26,000 acres
1906	5,500 ,,	1909	71,000 ,,
1907	5,800 ,,		

This land would probably not have been under cultivation at all but for the irrigation scheme.

Dry Land Farming.—Much attention is now being devoted to what is called dry land farming. This practice, which has been introduced from the United States, consists of thorough and repeated cultivation. The principal advocate of the system, Prof. Campbell, says that, in order to render cultivation of grain profitable under his system, an annual rainfall of from 14 to 18 inches is required. The regions round Swift Current and Calgary fall within these limits, the average annual precipitation at these places being 15·74 and 16·41 respectively. The regions round Medicine Hat and Macleod fall below the inferior limit, the average annual precipitation being only 13·72 and 12·17 respectively. Unfortunately the experiment of dry land farming is being tried in some regions where the natural conditions are quite unfavourable.

Live Stock.—The following shows the increase in live stock between 1901 and 1906:—

(000's omitted.)

—	Year	Horses	Milch Cows	Other Cattle	Sheep	Swine
N.W. Provinces	1901	340	244	698	182	200
Do.	1906	682	384	1,560	304	439

The increase in animals is thus, on the whole, rather greater than the increase in total population, and is much greater than that in rural population.

The Value of Land.—According to the census returns of 1901 the mean value of land in farms of five acres and upwards was, in Manitoba, $10·53 (£2 3*s.* 4*d.*) per acre, and in the North-West Territories $5·48 (£1 2*s.* 7*d.*) per acre. The report of the census of the Prairie Provinces in 1906 does not give any estimate of the value of

land. No general average price can, therefore, be given applicable to any year subsequent to 1901. The following statement is, however, useful from a comparative point of view:—

Sales of Lands belonging to Canadian Pacific Railway, 1901 *to* 1908.[1]

Year	Acres Sold	Average Price per Acre
1901	399,808	$3.15
1902	1,362,852	3.26
1903	2,639,617 [2]	3.67
1904	928,854	4.10
1905	509,386	4.80
1906	1,115,743	5.84
1907	994,840 [3]	5.92
1908	164,450	9.54

The total of agricultural lands in the Prairie Provinces still in the hands of the Company is 8,777,825 acres. These statistics show an advance in price of about 300 per cent. as between 1901 and 1908; they show also a sharp advance beginning in 1906, the price of 1908 being double that of 1905. As desirable homesteads are now obtainable from the Government gratuitously only at an increasing distance from the centres of population, further advance in the price of land from these relatively low prices must take place, provided the stream of immigration is maintained.

For land outside of the railway land grants, or in favourable positions inside of them, prices considerably higher than the averages quoted are now being paid. Land which in 1904 was being transferred at $10 to $15 per acre is now probably being transferred at from $15 to $20.

The price of agricultural land in the North-West of Canada is still considerably lower than that of similar land in the Western States of the Union.

In Manitoba and in Central Saskatchewan and Northern Alberta the loan companies may lend upon the security of land up to about one-half of the value placed upon the land by their inspectors, but in Southern Alberta it is not customary to lend more than $1,000 upon any quarter-section of 160 acres—that is, about $6 per acre; showing that the maximum value placed upon land in this region by the loan companies is $12 per acre.

At the present time the amount due to the Canadian Pacific Railway in deferred payments upon agricultural land and town-site sales is $14,000,000. The amount due to other railways on this account in the North-West is about $11,000,000. The total due on deferred payments is thus $25,000,000.

The average price of land sold from all Government land grants—Hudson Bay and railway lands—was in 1893 $2.93, in 1895 $1.94,

[1] From the annual reports of the Canadian Pacific Railway Company.

[2] Including large blocks of land sold to colonisation companies.

[3] Including land sold under contracts made previously. The average price for lands actually sold within the year was $8.09 per acre.

in 1897 $3.39, in 1899 $3.28, in 1904 $4.39, in 1906 $6.01, and in 1908 $8.78 per acre.[1]

Railway Development.—A general account of the earlier history of railway development in the North-West was given in my report of 1904. Since that date a very large amount of construction has been effected and projects of new lines are constantly being brought forward. It should, however, be recognised that in Canada, owing to the advisability of affording every encouragement to railway enterprise, the process of obtaining a railway charter is usually a very simple one.

The promoters of a new railway are not required to specify in other than a very general way the direction of the proposed line. They are not required to lay before Parliament or a Parliamentary Committee accurate surveys of the route. This elasticity has many advantages; but it has the disadvantage of rendering the railway companies somewhat casual in their applications to Parliament for charters. The result is that many hundreds of railway charters have been granted which have not resulted in any construction.

The following table exhibits the mileage of constructed lines in the Prairie Provinces in each year from 1905 till 1908:

—	1905	1906	1907	1908	
	Miles	Miles	Miles	Miles	
Canadian Pacific Railway: lines in the Prairie Provinces	3,854	4,097	4,276	4,376	
Grand Trunk Pacific Railway, under construction, Winnipeg to Wolf Creek	—	—	—	916	
Canadian Northern Railway:					
In operation	—	—	—	2,845	} 3,466
Under construction	—	—	—	621	
Great Northern Railway	—	—	—	173	

A very significant although as yet minor figure in the above table is the mileage of the Great Northern Railway. This railway system, whose main line crosses the great central plain parallel to and about seventy miles south of the international boundary, has been during the past few years sending up feeding lines at short intervals from its main line northwards to the boundary. There are at present thirteen of these feeding lines on the southern boundaries of Manitoba and Saskatchewan. Three of these lines enter Canadian territory, two of them extending into it for between seventy and eighty miles. Two other lines connect with Canadian lines. The remaining eight lines have their termini at, or almost at, the frontier. It cannot be supposed that their progress will be permanently arrested there. The President of the Great Northern, Mr. James J. Hill, is a Canadian. He was one of the first to recognise the agricultural value of the North-West, and there can be no doubt about the nature of his designs in pushing feeding lines to his system up into the prairies. It is very clear that in the first place he intends to haul out wheat to the mills of Minneapolis and St. Paul. It is very clear also that he anticipates at no distant date the adoption of a policy of reciprocity by the United States and Canada, and the freer movement of manufactured goods across the line northwards. It would be idle to

[1] *Report of Department of Interior*, 1908, Ottawa, 1909.

ignore that this 'invasion' of Canadian territory by Mr. Hill may not only result in competition with the Canadian railway lines, but must necessarily bring the manufacturers of the Middle West into competition with the manufacturers of Eastern Canada. The conditions in the United States are resulting in the westward development of manufactures, so that the western manufacturers in the United States would compete with the eastern manufacturers in Canada at great advantage, in respect to distance, in a market in the development of which Eastern Canada has incurred considerable sacrifices.

Estimates.—In my report of 1904 I quoted, among other estimates, an estimate of the maximum productivity of the North-West of Canada, which had been made for the purposes of the report by two highly responsible and well-informed experts in North-West settlement and agriculture. This estimate (referred to in the report as Estimate No. 1) ascribed to the region a possible total area annually available for wheat cultivation of 13,750,000 acres, and a possible total yield from this area of 254,375,000 bushels. The authors, however, desire me to say that although the data available in 1904, and the conditions, so far as they could be foreseen at that time, did not justify a higher estimate, they now consider that, provided 'intense cultivation, coupled with summer fallowing,' be applied consistently to the western portion of Southern Saskatchewan and to the whole of Southern Alberta, it would be possible to add to their original estimate of 13,750,000 acres annually available for wheat production an area of 3,500,000 acres. They think that this area might be calculated upon ultimately to produce, at 18 bushels per acre, a quantity of 63,000,000 bushels. If this quantity be added to the quantity formerly estimated, the result will be 317,375,000 bushels. This total quantity would be sufficient, in the opinion of the authors, to provide ultimately 232,250,000 bushels available for export. But they do not say at what period this is at all likely to be realised. I did not assume any responsibility for the original estimate, nor do I do so for this amendment.

The reasons why the anticipations of the more sanguine of the prophets of the North-West with regard to wheat production have not been realised may be generally ascribed to the fact that due attention was not paid to the number of factors which were necessary to produce the desired result.

Apart from the variability of the seasons and the liability of the crop in any and every year to damage from deficiency or from excess of precipitation, from hailstorms and from insect pests, there is the inevitable influence of the prices of the various crops upon their proportional cultivation, and there is also to be taken into account the circumstance that an increase of the acreage under cultivation is not always accompanied by maintenance of the yield per acre.

The principal factors to be taken into account in forming an estimate of the productivity of any country in the future may be classified as follows:—

1. The increase of the rural population.
2. The suitability of different portions of the area for cultivation of a particular character, and the appropriateness and purity of the seed, together with the degree of its acclimatisation when in a new habitat.

3. Personal aptitude on the part of the cultivators and their experience of methods of farming suitable for the soil in question.
4. Prices of grain and fluctuations of demand.
5. Facilities for transportation.
6. Variations of meteorological conditions.
7. Risk of damage from insect pests.

Conclusion.—No one who examines the statistics of agricultural production in the North-West since 1883 can fail to be astonished at the truly marvellous progress which the country has made during the short period of twenty-six years which has elapsed since then. In 1883 the population was insignificant. One railway line had just been constructed—indeed, at that date it was not completed to the coast. Now in the three provinces there are three great lines of railway, with another forcing its way in from the United States. The population is upwards of a million, and agricultural productivity has been advancing by leaps and bounds. The country needs no fantastic exaggeration to draw attention either to its achievements or to its possibilities. What it needs at present is cool estimate of these and consolidation rather than excessive expansion. A vast amount of energy and much capital have been wasted in attempts to exploit regions which are and must for long remain distant from markets, while fertile soils easy of access have remained under cultivation of a highly primitive character. The immense natural resources of the rich soil of Manitoba and of portions of Saskatchewan and Alberta are not even yet being fully exploited. Very considerable improvements in agricultural methods must yet take place if these resources are to be fully utilised.

The Development of Wheat Culture in North America.
By Professor ALBERT PERRY BRIGHAM.

[Ordered by the General Committee to be printed *in extenso.*]

IN the year 1602, on one of the Elizabeth Islands, off the present coast of Massachusetts, Bartholomew Gosnold made trial plantings of wheat and other grains. The Spaniards had earlier brought wheat to Mexico, but this was probably the first wheat sown within the boundaries of the United States. Nearly twenty years later wheat was sown at Plymouth, without success the first season, but with returns afterward. The grain extended itself among the New England colonies, and about 1700 there are records of shipments, as from Norwalk to Boston and Boston to Virginia. As the eighteenth century progressed, however, wheat declined, except as sown on fresh clearings, and was brought in from New York and the Southern colonies. That wheat was already moving westward is shown by the fact that New England traders bought New York wheat, ground it in their own mills, and sold it in the West Indies. To revive wheat culture Massachusetts laid a duty on the product to be paid as a bounty to farmers, but Weeden tersely says that 'the duty could not counteract climate and soil nor feed the fishermen.'

There is early record of wheat in Virginia, for in 1607 the Council informed the Council in England that they had fortified themselves against Indians, and had 'sown good store of wheat.' The first sowings

of English seed at Jamestown seem not to have been very successful. By 1800 wheat was raised along the entire Atlantic border except the southern parts of the coastal plain, but the Middle States from New York to Virginia assumed pre-eminence and held the centre of wheat for more than a generation. Meantime in 1769 missionaries carried the grain to California. There was important export to the West Indies in the early years of the Federal Government, until Great Britain shut out the ships of the United States from this trade. In 1787 wheat was among American exports to Mauritius. But it was long before the United States assumed a commanding position as a purveyor of bread, for in the decade 1830-40 she imported several million bushels of wheat to feed her own population.

In the later years of the eighteenth and the first decades of the nineteenth century western New York, or the Genesee country, proved its suitability in soil and climate for the growing of winter wheat. On the completion of the Erie Canal in 1825 the industry was favoured by suitable prices, the region was the famous wheat centre of the country, and Rochester was relatively as important for primary market facilities and milling as Minneapolis is to-day. The primacy of western New York was held until wheat began strongly to occupy the States north of the Ohio River.

Before tracing the westward march of the wheat centre it will be useful to survey the expansion of acreage and production during recent decades, or since 1866. It is this period of progress which has more than historical interest, since it has to do with any forecast of the future. From 1866 to 1875 the acreage in the United States varied between 15 to 26 millions, and there was a consistent rise from the beginning to the end of the decade. In the following ten years, to 1885, the range was from 26 to 39 million acres, giving on the whole a steady increase, but showing only 34 million acres in 1885. The period 1886-1895 ranged from 34 to 39 million, with smaller acreage in the later years. From 1896 to 1905 the minimum was 34 and the maximum 49 million, but from 1898 to the present time the limits have been 42 and 49 million acres. The highest figure—49 million acres—has been reached twice, in 1901 and 1903, and the significant element in the figures is the high average of the last dozen years.

Turning to production, the total for 1866 in the United States was 151 million bushels. In the next year, 1867, production passed the 200 million mark permanently. Another milestone was passed in 1874 with 308 millions. In 1878 the crop was 420 millions, and in 1882 504 millions. There were fluctuations in the following years, for production from 1883 to 1890 only once reached the 500 million mark, but 1891 made a showing of 611 millions, and 1898 brought 675 million bushels. The average from 1898 to 1908 has been 643 million bushels, and the maximum was, in 1901, 748 million bushels.

If single States be considered, some curious fluctuations are observable. Thus Kansas has never attained even fourth place in a census year, yet holds the State record with her crop of 99 million bushels in 1901. She has at least four times passed Minnesota's record of 80 million bushels. Minnesota dropped from 68 millions in 1899 to 51 millions in 1900, and leaped to 80 millions in 1901. North Dakota in the same years went from 51 to 13 and back to 59 millions. Kansas

in those years made a steady gain from 36 to 82 and 99 millions. Production is so widely distributed, however, that the general total for the country is much more stable.

For an orderly review of the movement of wheat from east to west in the United States four regions may be distinguished as follows: (1) the middle Atlantic States from New York to Virginia, including especially Pennsylvania and Maryland; (2) the five States of the 'Old North-West,' lying between the Ohio River and the Great Lakes; (3) seven States west of the Mississippi River, including Missouri and Kansas on the south and Minnesota and North Dakota on the north, the wheat belt reaching to the arid parts of the Great Plains; (4) the Cordilleran region, extending to the Pacific Coast.

The first of these regions was the North American centre of wheat from the first full establishment of the crop in the colonies until the Erie Canal and other means of communication opened to the east the possibilities of the Old North-West. The crops of New York for seven census years are as follows (the crop of 1908 is also included):

1839	12,286,418	bushels
1849	13,121,498	,,
1859	8,681,105	,,
1869	9,750,000	,,
1879	10,746,000	,,
1889	8,929,000	,,
1899	7,005,765	,,
1908	7,752,000	,,

The crop of 1905 rose above 10,000,000 bushels. Pennsylvania has had a fairly steady rise from 13,000,000 bushels in 1839 to 24,000,000 in 1899, and her crop for 1908 was 29,000,000, ranking this State among great producers, a fact not often recognised. Maryland has almost trebled since 1869, and has been above the ten-million mark since 1897, producing nearly 15,000,000 bushels in 1907. Virginia fluctuates, usually producing from six to ten million bushels. Even West Virginia, North Carolina, and Georgia show fairly steady records of several million bushels each. Taking those States which border the Atlantic, not including the Gulf, the total production of wheat in 1906 was 76 million bushels. In production per square mile Maryland held third place in the census of 1900 and in that of 1890, and her crop *per capita* in 1907 was more than 11 bushels. New York's production averages about one bushel *per capita*, and Pennsylvania's rate in her best years is about four bushels.

These figures concerning the sustained yield of many States on the eastern border have been given to show that the decline in wheat culture in this region is largely relative rather than absolute, a fact with which common impressions are at variance. It is true that as a whole the needs of the local population are not met, and that here is a large market for western wheat, but it is not true that the soils are exhausted, or that the Atlantic belt of States fails, or will ever fail, to make a substantial contribution to the bread supply of the nation. New England's contribution was never of great significance, but it is of interest to note that in recent years Maine and Vermont are the only States in that group which make a report of this cereal.

Before passing to the remaining major regions, it will be of interest

to show in the following table the rank of leading States in census years since 1839:

Rank of Leading States from the Sixth to the Twelfth Census.

Year	First	Second	Third	Fourth	Production of first State
					Bushels
1839	Ohio	Pennsylvania	New York	Wyoming	16,000,000
1849	Pennsylvania	Ohio	New York	Virginia	15,000,000
1859	Illinois	Indiana	Wisconsin	Ohio	23,000,000
1869	Illinois	Iowa	Ohio	Indiana	30,000,000
1879	Illinois	Indiana	Ohio	California	44,000,000
1889	Minnesota	California	Dakota	Indiana	45,000,000
1899	Minnesota	N. Dakota	S. Dakota	Ohio	68,000,000

The swift progress of wheat westward is well shown in the fact that Illinois, which is not named in 1849, takes first place in 1859. In the same sudden manner Iowa springs to second place in 1869, and Minnesota to first rank in 1889. It will be remarked that Ohio persistently keeps its place within the group of four for every census except one, and that is not the last one. In the same connection it should be observed that a State lying farther west, Illinois, after holding the primacy three times, passes at once out of the leading group. It has already been stated that banner State yields seem to avoid census years, for Illinois has a record of 60,000,000 bushels in 1880; Minnesota has risen to 78, 79, and 80 millions; North Dakota to 75 and 77 millions; and Kansas leads all, producing, in 1901, 99,079,304 bushels.

In 1839, while New York and Pennsylvania stood at 12 and 13 millions, Ohio had come to the front with 16 million bushels, and the great record of the second region was well begun. In forty-one years, from 1866 to 1906, Ohio produced 1,247,082,674 bushels—an average of 30,416,650 bushels. In the twenty-year period 1867-1886 the total falls more than 100 millions short of the total for the following equal period, 1887-1906. This is a most significant showing; and it should be added that, among all States, Ohio in the twelfth census, crop of 1899, stood first in product per square mile. Thus still further emphasis appears as to the importance of wheat grown east of the Mississippi River. Ohio has eight times exceeded 40,000,000 bushels.

The facts for Indiana are of similar magnitude. In 1860 she was second in production per square mile; she was first in 1870, 1880, and 1890, and fourth in 1900. Her total for forty-one years, 1866 to 1906, fell little short of that of Ohio, and she raised nearly 100,000,000 more in the second twenty-year period than the first. Like Ohio, Indiana exceeded 40,000,000 eight times in the period named, and raised more than 45,000,000 in 1908. Illinois has a total for forty-one years just under that of Indiana, being 1,160,352,208—an average of 28,301,273 bushels. In this State a balance of about 100,000,000 bushels is in favour of the first twenty-year period. While Ohio and Indiana contain only minor areas of prairie, Illinois is a typical prairie State, and goes heavily into the production of maize, in which it more than equals the combined crops of Indiana and Ohio.

Michigan and Wisconsin, the Lake States of this group, make a lesser showing in wheat, Michigan having produced in forty-one years two-thirds as much as any one of the three Ohio River States. The second twenty-year period shows a moderate decline over the first. In 1908, however, Michigan raised nearly 16,000,000 bushels—a product of no mean order. Her maximum of 34,000,000 in 1898 suggests what her possibilities are. Wisconsin has a different record, having often produced over 20,000,000 until 1884, and since 1892 has but three times reached 10,000,000. In 1908 she dropped to 3,328,000 bushels. This does not mean that this great State is unsuited to wheat. The crop suffered decadence through soil exhaustion, insect enemies, and the vast growth of dairying; but, with intelligent methods, there seems to be no reason why Wisconsin may not again stand well up in the wheat column. Mr. R. A. Moore, Agronomist of the College of Agriculture at the University of Wisconsin, expresses the opinion [1] that 'the pendulum will swing back to quite an extent.' He thinks the land of Wisconsin too rich for oat-raising, and that with rotation and other modern methods wheat can again be raised without impoverishing the soil. Before leaving the second group of States it will be of interest to note that of the entire crop of 1906, in the United States, of 735,000,000 bushels, 250,000,000 were grown east of the Mississippi River. This amounts to about 34 per cent., or slightly above one-third of the total. The third group of States forms the well-known present centre of wheat in the United States, and the figures need not be given in detail for individual States. Minnesota produced 10,000,000 bushels in 1867, and has steadily risen until, since 1895, her crop has never been less than 46,000,000 bushels, and has ranged up to 80,000,000. Iowa, as a prairie State, most resembles Illinois, but her wheat has seen larger decline. Thirty years ago the crop often passed 30,000,000 bushels, but in recent years runs from 8 to 14 millions. The reason is doubtless to be found in the expansion of maize and live-stock industries. Her average for forty-one years, 1866-1906, was 21,432,000 bushels. Missouri holds a strong average production in recent years of 20 to 30 million bushels, the maximum being 56,000,000 in 1902.

Kansas, Nebraska, and the two Dakotas may be called the Missouri River wheat States, and represent the newest and greatest development of wheat within the territory of the Republic. In 1862 Dakota Territory (before division) reported 11,000,000 bushels. This was but twenty-seven years before the present writing. Since 1897 the crop of North Dakota alone has but once fallen below 51,000,000 bushels, and rose in 1905 and 1906 to 75 and 77 millions. Nebraska's product is usually above 40,000,000 bushels. The total of the three leading wheat States of the present time is as follows for the ten years 1897 to 1906:

Minnesota	685,129,558	bushels
North Dakota	533,777,567	,,
Kansas	687,901,805	,,
Total	1,906,808,930	,,

[1] Letter of March 16, 1909.

Kansas has a slight lead over Minnesota. She has had several greater crops than her rival, but is subject to greater fluctuation. The average annual total for these three States, 1897-1906, was 190,000,000 bushels. The States of Oklahoma and Texas represent an extension of this belt along the more southern parts of the prairies and Great Plains. Oklahoma has a record in 1894 of two million bushels, with a fluctuating rise to 18 and 15 millions in 1906 and 1908. The crop is, of course, of longer standing in Texas, with report of nearly two million bushels in 1866 to a recent average of about 12 millions. It is an important fact that this belt, with its wide range of latitude, divides itself into a spring wheat region embracing the five States of Iowa, Nebraska, Minnesota, and the Dakotas, and a winter wheat section to the southward. In like manner Wisconsin and Washington, in the second and fourth of our major regions, raise spring wheat.

The Cordilleran region offers an older development of wheat in the three Pacific States, and a more recent progress in the intervening regions of the Rocky Mountain plateaux and Great Basin. This is in harmony with the extraordinary leap of the frontier a half-century ago, followed by the gradual occupation of intervening territory.

California reported 21,000,000 bushels so long ago as 1868. Her maximum crop of 45,000,000 bushels belongs to the year 1896. A comparison of two twenty-year periods, 1868-1887 and 1888-1907, shows but slight decline; but if two ten-year periods, 1888-1897 and 1898-1907, be taken, there is an important falling-off, due perhaps to the immense advance of horticulture and the progress of irrigation. California in 39 years produced 1,149,000,000 bushels of wheat. Oregon has had a somewhat uniform range of 10 to 16 million bushels since 1880, rising to 24,000,000 in 1898. Not quite 11 million bushels were produced in 1908. Washington, on the other hand, has seen conspicuous progress, and since 1897 has ranged between 20 and 34 million bushels. The greatest thousand-acre yield ever reported is ascribed to Eastern Washington in 1881—viz., 51,000 bushels.[1]

Outside of the coast States there are no large producers in the Cordilleran region. Idaho, Colorado, Utah, and Montana each grow several million bushels per annum, but in a general survey their chief interest has to do with their future possibilities under irrigation. The Cordilleran total for 1906 was 94,111,584 bushels. This is 18,000,000 bushels more than was grown in the Atlantic coast States in the same year, but the western area is several times greater.

The following table, from the twelfth census, gives the successive positions of the wheat centre of the United States for the half-century 1850-1900:

Wheat Centre, U.S., 1850–1900. (*Seconds omitted.*)

Census Year	N. Latitude	W. Longitude	Approximate Location by important Towns
1900	41° 39′	94° 59′	70 miles W. of Des Moines, Iowa.
1890	39° 33′	93° 9′	138 „ S. by E. of Des Moines (in Mo.).
1880	40° 36′	90° 30′	69 „ N.W. of Springfield, Illinois.
1870	40° 39′	88° 48′	82 „ N.E. of „ „
1860	39° 59′	86° 1′	18 „ N.E. of Indianapolis, Ind.
1850	40° 14′	81° 58′	57 „ E.N.E. of Columbus, Ohio.

[1] *Rep. Bureau of Statistics, Washington*, 1903, p. 69.

An examination of this movement brings out some interesting facts. The amount of westward migration in fifty years was 680 miles. The northward movement was about 99 miles. The latitude variation was marked by slight fluctuations for 40 years, and then in a single decade wheat moved more than 2° northward, owing to rapid increase in the North-West. The greatest westward movement was in the first decade, 1850-1860, amounting to more than 200 miles. The westward movement in the ten years 1890-1900 was a little less than 100 miles.

At the last census the centre of population was in south central Indiana; the centre of manufacture was in central Ohio; of corn in western Illinois between Springfield and St. Louis; of all cereals, on the Mississippi River near Keokuk, Iowa; and the centre of wheat was in western Iowa. In 1850 the corn and wheat centres were near each other in Ohio. Wheat has outrun all the other great interests in its westward march.

The present position of the centre of wheat raises a most interesting inquiry. The latest data are for 1908, and returns from a few minor States are not before the writer. For exact determination detailed figures for counties are used by the Census Bureau. But taking the State totals, it appears that 320,000,000 bushels, approximately, were raised in the States east of the Mississippi, plus the tier of States bordering the west bank of that river. This is a little less than half the crop, and would seem to carry the centre for 1908 out of Iowa and across the Missouri River. Considering latitude movement, it must be noted that California has fallen off, but this is partly offset by a decreased crop also in Oregon. The crops, however, of Kansas, Missouri, Illinois, and Indiana, which are mostly south of the centre of 1899, were much greater in relation to the total in 1908 than in 1899. It would seem clear, therefore, that for 1908 the centre has returned southward, and might probably be found in south-eastern Nebraska.

Passing to the inquiry as to the centre of wheat in North America, it is to be observed that the Canadian crop of 1908 [1] was 112,434,000 bushels.

To take this into account would move the centre as determined for the United States northward across a belt sufficient to raise half the Canadian product, or 56,000,000 bushels. Assuming the centre for the States as in south-eastern Nebraska in 1908, this belt would cross southern Iowa and the northern part of Illinois, Indiana, Ohio, and Pennsylvania. As these States are heavy growers, the belt would be narrow, and the centre for North America would not go higher in latitude than that for the States in 1899.

The greater part of Canadian wheat, about 92 out of 112 million bushels in 1908, is raised in the western provinces, and therefore westward of the centre for the States. Making allowance in a similar manner, the longitude centre for North America would be found by passing westward across a section of the Dakotas, Nebraska, Kansas, and Oklahoma, and would probably lie in Nebraska, 100 miles or less westward from Omaha. This is more than 500 miles from the Canadian border, and the Dominion's production must vastly increase before the 49th parallel will be approached.

The importance of the new development in the north is not, how-

[1] *Census and Statistics Monthly*, Ottawa, December 1908.

ever, thus measured. It is easy to conceive of a time in no distant future when the United States might raise 800,000,000 bushels and consume 700,000,000, while Canada might at the same time raise 400,000,000 and consume 100,000,000 bushels. It is easy to see that the northern country would even then hold a threefold more important place in the public markets of the world than her neighbour, even while the North American centre of production remained at some distance south of the international boundary.

The movement of wheat growing has been from east to west, and will now be from south to north. This is largely the movement of history, and follows the migration of the frontier in our continent. The direction has thus had an historical origin, and both the direction and the rate of movement have been conditioned by the development of transportation. The more special and local reasons for the shifting of wheat lend themselves to inquiry, and have perhaps been nowhere else so well discussed as by Mr. C. W. Thompson.[1] The subject of study is the shifting of wheat culture in Minnesota. This cereal has gone from south-east to north-west in that State. Olmstead County, in the south-east, is as fertile and as capable of large crops of wheat as the best Red River lands, and is as good now as it was in 1870. The one region is as favourable in soil and climate and as suited for the use of machinery as the other. But as population increases and land grows in value more must be allowed for rental, or interest on investment, and intensive, diversified farming replaces the more extensive wheat farming. The bonanza wheat farms tend to break up as the population grows, for with skinning processes and much hired help in one part of the year, and, it may well be added, with no stock or rotation of crops, there is no way to enrich the land, cultivate thoroughly, and thus increase the product of an acre. The acre must be put to crops and tillage that will enable it to bear its greater burden, and wheat must go elsewhere. Moreover, the best returns accrue where one man, the owner, and one set of farm machinery do most of the work. Such farms contain 160 to 170 acres of land. Hence not only does diversified farming drive out wheat in some measure, but the smaller wheat farm drives out the great bonanza farm with its thousands of acres, its enormous machines, and its small army of labourers.

It is therefore an error to think that wheat must pass or be in jeopardy with the elimination of the frontier. This has already been seen in the sustained wheat growth of the old North-West. In the census year 1899 more wheat was raised on farms of 100 to 175 acres than on those of any other specified size. Less than one-eleventh of the country's wheat grew on farms exceeding 1,000 acres. Almost one-fifth was raised on farms of less than 100 acres. Taking the whole country, the yield per acre on the smaller farms was slightly greater than the yield on the large farms, notwithstanding the fact that the latter were chiefly areas of virgin soil. Thus, while wheat has figured largely as a pioneer crop, to be grown on free or cheap land, these conditions are not so important as is supposed, and an old, highly cultivated country like France, raising nearly all its own wheat, offers the best of object lessons. Dondlinger,[2] while holding that much land will become too

[1] *Quart. Jour. of Econ.*, vol. xviii. 1904, p. 570.

[2] *The Book of Wheat*, p. 303.

valuable for wheat, thinks that lands now idle will be brought to its production, and even anticipates that the centre of wheat growing may reverse its historic direction of movement and return eastward.

In 1904 Dr. William Saunders reported that Fort Simpson, on the Mackenzie River, was the most northerly point from which samples of wheat had been received. This is about 62° N. lat. Dondlinger[1] is authority for the statement that spring wheat has been matured at Rampart and Dawson, still nearer the Arctic Circle. It is fair to say, however, that the latitude range of wheat in North America is from 30°, latitude of New Orleans, to 60°, latitude of the northern boundary of Saskatchewan and Alberta, a belt of 30°. The areas of large and assured production may, however, always remain between 35° and 55°, with more chance for northern than southern expansion. In Eurasia wheat reaches to Trondhjem (63½°) and northern Russia, to a point in India below the Tropic of Cancer (to 21°). This greater range of 40° is due to the cooling effects of the altitude of the high slopes and plateaux of northern India. By including the product of Mexico and the Central American States, though small, the North American range may also be greatly extended. Thus from Nicaragua to the Mackenzie River wheat reaches across 50° of latitude.

Wheat is so important that every effort will be made to widen its areal and its latitude range. This will be accomplished in part by irrigation. In the last census year, 1899, 99 per cent. of Arizona wheat was irrigated. This territory is a small producer, but Colorado and Utah, much larger growers, watered 84 and 57·4 per cent. respectively of their wheat lands. The three States of the Pacific coast, which are larger producers, irrigate but a small part of their wheat. In the year named all the Cordilleran States, with Nebraska added, irrigated 14·1 per cent. of their wheat fields, and raised on this area 17·7 per cent. of their crop. This shows that the yield can be enlarged, where wheat is already grown, by dry farming, as well as by bringing new lands under the ditch. The cost of irrigation works, however, may make extensive wheat growing impracticable, because other crops permit more intensive farming and offer larger returns. Our conclusion must be that only a moderate expansion of American wheat will be due to irrigation.

Agricultural enterprise and the importation of varieties may be expected to show, and indeed are now showing, much greater results. Some time ago the Department of Agriculture brought from the Crimea and naturalised in Kansas a red winter wheat which is described as high in hardness, yield, milling value, and resistance to disease. Various other Russian sorts have served to push the wheat areas westward into the vast semi-arid regions where water is too limited for extensive irrigation, and which, therefore, must be given over to pasturage unless the crops can be adjusted to small rainfall. These varieties belong to the durum, or so-called macaroni wheats, and are commonly raised not only in Russia, but Turkestan, Algeria, and other parts of the world where the climate is dry and hot.

A climatic comparison of the Great Plains, which cannot grow the usual varieties beyond the one-hundredth meridian, shows that the American semi-arid belt has three inches more rainfall than the great

[1] *The Book of Wheat*, p. 5.

home of macaroni wheat on the plains of the Volga.[1] The author to whom reference is here made also characterises the soils of the Plains as a counterpart of the 'black earth' of Russia. The first introduction of Russian durum was made in the United States in 1864, and experimental proof of its value has become conclusive and final. The area suited to its growth extends in a wide north and south belt through the Dakotas, Kansas, Colorado, Oklahoma, and Texas. In 1906 the production of durum wheat in the United States had risen to 50,000,000 bushels, with a growing export demand in Southern Europe, as its qualities are known, and a larger domestic use accompanying development in milling methods and the enlarging of the macaroni industry.

Both yield and areal expansion have been assiduously promoted in North America by skilful selection and cross-breeding. Professor W. M. Hayes estimates that farmers have increased the yield of maize 20 per cent. by selecting the best ears, and they have also pushed the corn belt northward.[2] According to the same writer, the past century saw the sugar content of the sugar beet doubled through selection by European seed-growers. Other important results from plant-breeding and selection are familiar, and it has been shown by ample experience that no vegetable product is more plastic than wheat. Different conditions in the United States have modified wheats in colour, hardness, moisture, gluten, and albumenoids, and have changed winter to spring and spring to winter wheats. According to Hayes, a single variety known as Minnesota No. 169, bred at the experiment stations, has raised the yield in that State no less than 5-10 per cent.

Among the most persistent and successful efforts in breeding new varieties are those carried out under the direction of Dr. William Saunders at the Central Experimental Farm, Ottawa, and at the other experiment stations of the Dominion. This work has peculiar interest, because one of its chief aims is to breed wheat suited to northern conditions. Where vast areas are suited to wheat in surface, soil, and potential transportation, it is of the utmost importance to secure early ripening and conformity to the shortness of the summer season. At the same time high quality must be preserved, since the chief present value of the crop is for the purposes of export.

The most important of these new varieties are the Preston, Stanley, Huron, and Percy.[3] Preston is named by Dr. Saunders as the best-known of the early wheats, and the four named were all originated at Ottawa in 1888 by crossing Red or White Fife with Ladoga. As compared with the old and standard Red Fife, these varieties all ripen four to twelve days earlier. Their yield, colour of flour, baking strength, and market value are all high, and the early ripening therefore extends the wheat belt northward to a significant degree. The parent Fife holds its place where early frosts are not feared; but the new breeds are invaluable in latitudes where a single early frost puts in jeopardy the labours of an entire year. We need not suppose that the process of adjustment to northern conditions has yet reached its limit.

[1] *Macaroni Wheats*, M. A. Carleton, Bull. No. 3, Bureau of Plant Industry, U.S. Department of Agriculture.

[2] *Year Book, U.S. of Agriculture*, 1901, p. 218.

[3] *Preston and other Early-ripening Wheats*, C. E. Saunders, Cerealist. Bull. of Central Experimental Farm, March, 1908.

The limits of this paper allow little more than mere mention of the profound effects on American wheat culture of conditions of production, manufacture, and transportation. The vast interior plain of North America, ranging from warm to cold-temperate as one passes from the Lower Mississippi to the Upper Mackenzie, has provided not only an unlimited expanse of soil, but offers a surface on which the modern machinery of production and transportation can operate. The plains of Russia and Argentina fall into natural comparison, but here the inventive genius and enterprise of the North American step in and give present supremacy, and, so far as we can see, this advantage will project itself over many years of the future.

We may, indeed, consider transportation as important as production, for otherwise wheat has little value to grower or consumer. Genesee wheat was little more than the bread of a few pioneers before the digging of the Erie Canal. To send a barrel of flour from western New York to Philadelphia cost $1.25.[1] Grain and flour in general could not bear the cost of transportation for more than 150 miles. In 1825, 50 cents per bushel was considered a large price on the Ohio River; and indeed, after a haul of several days to the river, the farmer commonly got 25 to 30 cents, and that in trade.[2] In that year wheat brought 25 cents in Illinois, 80 cents in Petersburg, Virginia, and flour $6 per barrel in Charleston, South Carolina. Similar differences prevailed in France, for in 1847 the average difference of the price per hectolitre in different parts of that country was 26 francs. Since 1870 the difference has averaged 3.55 francs.[3] Similarly prices have become equalised among nations as well as sections, and there is now a world market for wheat which, according to the experts in economics, cannot be widely or for long disturbed by speculation. The world's crop is becoming available for the world's hunger, and in this transformation the Transatlantic highway and the American railway and waterway have borne the largest part. The same author says: 'In respect to no other one article has change in the conditions of production and distribution been productive of such momentous consequences as in the case of wheat.'

It was the building of railroads and the development of lake navigation that enabled the States of the old North-West to replace the Atlantic States as the grain centre, and in turn gave the new North-West its present supremacy. And now history repeats itself in the Canadian North-West, in the multiplication of trunk lines and spurs and in the extension of through lines of transportation from Europe to the St. Lawrence, from the St. Lawrence to the Pacific, and from Vancouver and Prince Rupert to the Orient. The grain elevator also has extended its useful sway from Buffalo, Chicago, Minneapolis, and Duluth to Winnipeg, Prince Albert, and Edmonton. The development of Pacific steamship lines, the opening of the Mississippi, a canal from Lake Huron to tidewater, and the possible utilisation of the Hudson Bay route are all further steps in making North America the central bread-grower of the world.

The future of the United States in the universal wheat market is of peculiar interest both to her own citizens and to those of Canada.

[1] McMaster, *History of the United States*, iii. p. 463.
[2] F. J. Turner in *American Nation*, vol. xiv. 105-106.
[3] Rand's *Economic History since 1763*, p. 315.

This depends on two factors—possible production and the possible population. As to both of these factors and the resulting future in export trade, opinions differ greatly. So acute an observer of our affairs as M. Leroy-Beaulieu,[1] referring to the fact that for some years increase in wheat exports has not been more rapid than growth of population, believes this will continue to hold true. He grants that export wheat is likely to remain at its present high level for some time to come, but little increase is probable, the predominance of agricultural exports will pass and manufactured products will take their place.

Mr. James J. Hill is yet more emphatic,[2] holding that 'we are approaching the point where our wheat product will be needed for our own uses, and we shall cease to be an exporter of grain. There is still some room in Canada, but it will soon be filled.' That there is some inconsistency in Mr. Hill's utterance appears in the view expressed in the preceding paragraph of his address, that only one-half of our farm areas is improved, and that this half might be made, by ordinary care and intelligence, to double its production.

Similar views are set forth by Mr. J. C. Williams,[3] who, referring to a falling-off in production and the increase of home use, thinks it 'quite possible' that the United States will become a permanent importer of wheat under normal conditions. To these opinions may be added that of Dondlinger:[4] 'With the increase of population and local consumption, the internal and export movement of wheat will greatly decrease, and American wheat will be a factor of declining importance in the international grain trade.' By American this author no doubt means the product of the United States. He holds that diversification and rise of land values will decrease wheat acreage in the west, though this loss may be in a measure offset by the adoption of new areas in the east and south.

In addition to these recent views it is not out of place to observe that other and earlier prophecies now read curiously in the light of history. Edgar[5] quotes the conviction of John H. Klippart, writing in Ohio in 1859, that the limits of the wheat area in the United States had been reached, and that, without increase of yield, the surplus would 'by the next census be measured by the algebraic quantity of minus.' So late as 1884 a high foreign authority expressed the opinion that the wheat trade in America had reached its limit, because of the exhaustion of the soil and the prohibitive cost of freight from remote districts. These forecasts may well have less real basis than those of recent years, but they at least hint at the pitfalls of prophecy and admonish us that human wisdom rarely covers all the unknown factors of a hard problem.

It will be prudent, therefore, to discuss the first of the two great factors in a wholly general manner. Can the United States largely increase its crop of wheat? Another wheat expert, Mr. E. C. Parker, writing in the 'Century Magazine' in September 1908, less than one

[1] *The United States in the Twentieth Century.*
[2] Conference of Governors 1908, *Proceedings*, p. 72.
[3] *Science*, N.S., xxi. 1905, p. 458.
[4] *The Book of Wheat*, p. 305.
[5] *The Story of a Grain of Wheat*, p. 87.

year ago, thinks the home demand will soon stop exporting in any quantity. At the same time he exhibits a strong array of means for strengthening the industry, and considers it 'hard to imagine a wheat famine in the immediate future.' Indeed, to fear for the wheat supply of many generations to come is pessimistic. According to Mr. Parker, we shall have bread enough, but not to spare.

Some means of increasing the product have been considered. It may be admitted that increase by irrigation for export uses is more than doubtful, but it may also be claimed that watered lands will largely care for the bread of the increasing Cordilleran population. If agricultural exploration has given us a crop of 50,000,000 bushels of durum wheats, the extent of available semi-arid lands suggests the probability of a large increase on demand. The production of early wheats will increase the Canadian crop more than that of its neighbour, but may aid in naturalising the grain at higher altitudes in the west. There is an unknown amount of land east of the Mississippi to be rendered fit for cereals by drainage, for, as compared with Europe, we of North America know nothing about utilising waste lands.

It is wise, therefore, to accept the dictum of a recent writer[1] that 'the future growth of cereal production will depend more upon improved methods of agriculture than upon the addition of new lands.' Anyone with faith in the new American agriculture must, it seems to the writer, have large faith here. A table of comparative yields per acre is not a pleasant sight to a citizen of the United States. The record of a few leading countries is appended. It gives the average, 1899 to 1904:—

United Kingdom ...	32·4	Hungary	17·6
Germany	28·1	United States	13·7
France	20·8	European Russia ...	9·7

The yield for Canada in 1904 was 16·8 bushels. In 1908 Canada's yield of spring wheat (the bulk of her crop) was 16·03 bushels, and of winter wheat 24·40 bushels. It should be added that in the United States the yield for 1904 was 14·5 bushels. For 1908 the yield was slightly under 14 bushels. Reasonable confidence in the soil and future tillage south of the forty-ninth parallel offer hope of large increase in the coming generation. Sixty years ago France was producing less than 15 bushels per acre. A duty on imports practically prohibitive has forced the adoption of thorough tillage and made it necessary for the French farmer to fertilise, and use every other expedient for winning the largest result from his small fields. It may be said that labour conditions are very different, but the fact remains that these anciently tilled fields have been made to grow a vastly larger crop than they raised seventy-five years ago. It is significant that the farms of the United States average 150 acres, while the French farms average twenty acres. Leroy-Beaulieu refers to our small outlay for labour as evidence that we have little intensive cultivation. The writer of this paper has elsewhere shown[2] that east of the arid region we had, at the last census, but one agricultural worker for each

[1] E. L. Bogart, *Economic History of the United States*, p. 295.

[2] 'Distribution of Population in the United States,' *Geog. Jour.*, October 1903, p. 383.

91·4 acres. Such facts are eloquent of our future possibilities, not only in wheat, but in every product of the soil. What is true of the United States is more true of Canada, with its ample soils and sparse population.

A South Carolina writer[1] asserts that tillage has in some cases made an increase per acre of more than eight bushels. Professor Harry Snyder, of the University of Minnesota, asserts that the 'yield per acre of wheat in the United States is much less than the soils are capable of producing.'[2]

Mr. W. C. Ford, referring to the increased yields of France,[3] utters a general principle which should be the inspiration of every North American farmer and the basis of reasonable optimism for every loyal citizen of the New World: 'To this march of scientific agriculture there is no end.' California is said to have used six times as much artificial fertiliser in 1900 as in 1890, and one of the latest bulletins of the Minnesota Agricultural Experiment Station, of date June 1908, deals with the rotation of crops. Fertilisers, even in the Red River valley, are said to have increased the yield in some cases from 15 to 26 bushels. Minnesota is not an old State, but is taking up the problems of the present and the future, and is quoted here, not as an exception, but as a sample of general practice throughout the United States.

The other great factor in the wheat problem is the increase of population. Space forbids more than a word. The writer has given his views on this somewhat difficult subject in another place.[4] In his belief the ordinary prophecies of increase in the coming generation are exaggerations. Mr. James J. Hill, for example, thinks we shall have 200,000,000 people in the United States by 1950. Let the reader observe the following rates of increase:

Decade before 1880	30·2 per cent. increase
Decade before 1890	25·5 per cent. increase
Decade before 1900	20·7 per cent. increase

Here is a drop of nearly 5 per cent. in each decade. The population in 1899 (census of 1900) was 76,085,794. The population for the thirteenth census, now about to be taken, may be estimated at 88,000,000. This gives an increase of 15·6 per cent. in the last decade and maintains the descending rate of previous periods. If we allow a drop of only 1 per cent. for coming decades, there would be in 1949, the year of the seventeenth census, a population in round numbers of 144,000,000. This is a sufficient comment on the prevailing extravagances in estimating our future numbers in the United States. It is, perhaps, more possible that 1950 will not see a population of more than 130,000,000. But let us grant 150,000,000 in no very distant future. At six bushels *per capita*, 900,000,000 would be needed at home. More than 700,000,000 bushels have already been raised in one year. An increase of four bushels per acre on present wheat lands would about fill the gap. An increase of ten to twelve million acres under good tillage would still provide for the present scale of export. It is safe to

[1] *S.C. Bull.*, 56, 12.
[2] *Pop. Sci. Mo.*, 53, 1898, p. 8.
[3] Art. 'Wheat,' *Ency. Americana.*
[4] *Pop. Sci. Mo.*, September 1909, 'Capacity of the United States for Population.'

expect that this cereal, as an essential food, will press for its place, and all reclamation and adaptation of lands now idle to other crops will tend to release land for wheat.

Regarding it as fairly probable that the United States will not materially increase its exports of wheat, the Canadian product assumes new interest, not only for the farmer and economist of the Dominion, but for every student of the subject. It would be needless—and, indeed, presuming—to bring to this place from across the border detailed statements as to the history, or confident predictions as to the future, of Canadian wheat.

In comparison with some of its competitors, Canada is old in the industry, having raised over 20,000,000 bushels in 1827, while Argentina began to raise wheat in 1882. Recent developments in the North-West belong to the experience of many who are still foremost in the field. Fort Garry has been Winnipeg but for a single generation, and the Canadian Pacific Railway entered the city so late as 1881. It has already been observed that the Canadian yield is high, owing to the native fertility of its prairies, and the greatest crop ever raised from unfertilised land is credited to Western Canada in 1901, when 63,425,000 bushels were raised on something more than 2,500,000 acres, an average yield of more than 25 bushels.

The following tables show the progress of wheat in Manitoba, Saskatchewan, and Alberta from 1900 to 1908. The figures are kindly furnished to the writer by Mr. A. Blue, Chief Officer, Census and Statistics Office.[1] The product for 1908 is taken from the 'Census and Statistics Monthly,' Ottawa, December 1908:—

MANITOBA.

1900	... 18,352,929 bushels	1905	... 47,626,586 bushels
1901	... 50,502,035 ,,	1906	... 54,472,198 ,,
1902	... 53,077,267 ,,	1907	... 39,688,266 ,,
1903	... 40,116,878 ,,	1908	... 50,269,000 ,,
1904	... 39,162,458 ,,		

SASKATCHEWAN.

1900	... 4,306,091 bushels	1905	... 31,799,198 bushels
1901	... 11,956,069 ,,	1906	... 50,182,359 ,,
1902	... 13,110,330 ,,	1907	... 27,691,601 ,,
1903	... 15,121,015 ,,	1908	... 34,742,000 ,,
1904	... 15,944,730 ,,		

ALBERTA.

1900	... 797,839 bushels	1905	... 3,035,843 bushels
1901	... 857,713 ,,	1906	... 5,932,267 ,,
1902	... 850,122 ,,	1907	... 4,194,435 ,,
1903	... 1,200,598 ,,	1908	... 6,842,000 ,,
1904	... 938,200 ,,		

The exports of Canadian wheat ranged from sixteen and nine millions respectively in the years 1900 and 1901 to a maximum of 43,654,668 bushels in 1908. The Ontario crop is usually over twenty million bushels, but it is from the North-Western provinces that future growth is chiefly expected. Dr. William Saunders[2] states that during 1908 experiments have been carried on in the Peace River district, at Fort Vermilion, 350 miles north of Edmonton, where the crop amounted

[1] Letters of March 19 and 24, 1909.
[2] Letter to the writer of date March 15, 1909.

to 35,000 bushels. He adds the important statement that 'there seem to be no climatic differences there which are more difficult to be overcome than in the immediate vicinity of Edmonton.'

If there be prophecy as to Canada's future product, her own experts must play the part of seer. We have not seen that Dr. Saunders retracts or in any way modifies his 'reasonable prophecy' of 1904—that wheat grown on one-fourth of the land suited to it in the Canadian North-West, with the yield of Manitoba for the previous decade, would bring a crop of more than 800 million bushels, which, as he shows, would feed 30,000,000 people in Canada and three times supply the import need of Great Britain. If there be such a surplus of good soil as three-fourths, this would leave ample room for diversified crops, and for such rotations and fallowing as might be needful in future years to meet the declining production of the prairie soils.

Sir William Crookes in 1898 allowed from credible estimates six million acres of wheat land for Canada in the following twelve years. The acreage of 1908, after ten years, but slightly exceeded his figure. His fears, however, as to inadequate population to work the wheat lands are not likely to be realised. When he read his address at Bristol he could not have foreseen that spectacular migration across the border from the South, which now plays so large a *rôle* in the North-West. In the year 1898 this immigration brought 9,119 settlers into Canada. In the fiscal year of 1908-09 the number had risen to 59,832, and had become a theme of interest to both countries. Sixty thousand settlers, mainly going to wheat farms, and bringing in capital and experience, means immediate and large expansion of Canadian wheat, and an annual product *per capita* far exceeding anything that any wheat-raising country has known.

The population of Canada has always increased slowly, being 240,000 in 1801 and rising in 1901 to 5,371,315. But it is precisely in the wheat provinces that recent percentages of increase have been enormous, so that Canada promises to give herself to a great agricultural specialty, and remotely, if ever, will come the time when her population will press hard upon her productive capacity. Unlike the United States, she must confine herself to products of temperate climates, and her greatest reliance for exchange must, it would seem, be breadstuffs. Immigration into Canada since 1901 has brought more than one million people, and if the population in 1908 were 7,000,000, there was a *per capita* production of wheat of 16 bushels. The ratio will no doubt be much higher in the near future.

It is easy to refute prophecies which the event has already nullified, but it is, nevertheless, sometimes useful to recall them. In his famous address of 1898 Sir William Crookes concedes his statements to be alarming, but asserts they are based on stubborn facts, and that 'England and all civilised nations are in deadly peril of not having enough to eat; . . . as mouths multiply, food resources dwindle; . . . our wheat-producing soil is totally unequal to the strain put upon it.' Great Britain then needed 240,000,000 bushels of wheat, of which she raised one-fourth and imported the rest. Sir William regards as a burning question what to do to avert starvation if crops should fail or nations combine in hostility, especially in view of the world's increase of bread-eaters. The wheat-growing area was strictly limited; there was no land left in the United States without cutting into maize, hay, and

other crops, and the export of 145,000,000 bushels would soon be required at home. In the world's crop for 1897-1898 he gives the United States 510,000,000 bushels. As it turned out, there were in the process of harvest, when Sir William was reading, 675,000,000. The average crop for eleven years, 1898-1908, has been 643,668,762 bushels, giving an average increase beyond his figure of 133,668,000 bushels—almost enough to cover the export amount then stated. The world's crop for 1897-98 was said to be 1,921,000,000 bushels, leaving a deficit, but for supplies carried over, of 400,000,000. He thought the wheat lands of all nations brought to their utmost capacity might raise the total to 3,340,000,000, or within 17,000,000 bushels of what the eaters of wheat bread would require in 1931. We now know that the world's crop eight years later, or in 1906, was 3,423,134,000 bushels, and the limit is nowhere in sight, and cannot be conjectured within a billion bushels by the keenest student of the wheat problem. Sir William felt that performance had lagged behind promise in Canada, and he observed the modest export of less than 9,000,000 bushels, which has now been raised nearly fivefold.

It is hazardous to set limits to wheat, in view of possible unknown factors of production, and discussions have not taken sufficient account of the limitation of population which exhibits itself among the nations of higher standards, which are precisely the bread-eating peoples. Without regard to wheat this limitation would be operative, but any pressure on the wheat supply would foreshadow itself before the pinch came, and would tend to still further restriction of population. We may therefore comfortably come back to an earlier conclusion of an American economist:[1] 'In short, it would seem as if the world in general, for the first time in its history, has now good and sufficient reasons for feeling free from all apprehensions of a scarcity or dearness of bread.'

Looking, in conclusion, at the world field, the only great importing countries are in Western Europe, or more truly North-Western Europe. Any increased demand in that region should readily be met by developments in Canada, Russia, Argentina, Egypt, India, South Africa, and Australia. We may thus even leave out the United States, and we might omit India, should ampler distribution of her wheat at home be made to avert her too frequent periods of famine. Of the greater producers, Argentina is far from her market, is undeveloped, and in some degree uncertain. Russia is backward, and will not for more than a generation bring her vast resources to full effect in the world's market. It is North America which has the land, the progressive appliances, the skilled energy of production, and the facilities of transportation to supply the bread market of coming decades. No citizen of the great Republic need harbour a jealous thought if in that market the major place should come to his northern neighbour.

[1] Mr. D. A. Wells in *Recent Economic Changes*, p. 177 (1889).

Gaseous Explosions.—Second Report of the Committee, consisting of Sir W. H. Preece (*Chairman*), Mr. Dugald Clerk *and* Professor Bertram Hopkinson (*Joint Secretaries*), Professors Bone, Burstall, Callendar, Coker, Dalby, *and* Dixon, Drs. Glazebrook *and* Hele-Shaw, Professors Petavel, Smithells, *and* Watson, Dr. Harker, Lieut.-Colonel Holden, *and* Captain Sankey, *appointed for the Investigation of Gaseous Explosions, with special reference to Temperature.*

[Plates V.–VIII.]

During the session 1908-09 the work of the Committee consisted partly of new investigations and partly of study and critical discussion of English and Continental work already published. The new work has necessitated the design and construction of much new apparatus, and especially of new optical indicators.

Four meetings have been held in Mr. Dugald Clerk's laboratory in London and one at the National Physical Laboratory.

The five meetings have been excellently attended. Seven Notes have been presented and discussed:—

No. 7.	The Analyses of Exhaust Gases from the Petrol Engine	W. Watson.
No. 8.	Some Experiments on Chemical Equilibrium in Gaseous Explosive Mixtures	Dugald Clerk.
No. 9.	Deville's Experiments on the Dissociation of Gases	J. A. Harker.
No. 10.	On Radiation in a Gaseous Explosion	B. Hopkinson.
No. 11.	The Alternate Compression and Expansion of Dry Air in an Engine Cylinder	Dugald Clerk.
No. 12.	Direct Measurement of the Temperature of the Working Fluid in a Gas-Engine Cylinder	W. E. Dalby.
No. 13.	The Temperatures reached in the Compression of Air	B. Hopkinson.

It will be observed that Notes Nos. 7, 8, and 9, by Professor Watson, Mr. Dugald Clerk, and Dr. Harker, deal with the question of Chemical Equilibrium, while Note No. 10, by Professor Hopkinson, though dealing primarily with radiation, also bears upon the same subject. Notes Nos. 11 and 13, by Clerk and Hopkinson, are devoted to the study of the compression and expansion of cold air within a cylinder, while Note No. 12, by Professor Dalby, deals with the direct determination of the suction temperature in a gas-engine when working.

Professor H. B. Dixon has continued his experiments on the ignition point of gases by two methods. In the first the gases are heated separately before being brought into contact, and the temperature is determined at which the meeting gases enflame. The combustible gas is led up a narrow tube of glass or quartz in the axis of a larger tube heated electrically; air or oxygen passes up the space between the two tubes. The wider the

tubes and the quicker the flow of gases, *i.e.*, the less the contact action of the heated surfaces on the mixing gases, the *lower* the ignition-temperature was found to be. Experiments made between half an atmosphere and two atmospheres showed a lowering of the ignition temperature with increase of pressure.[1]

In the second method the mixed gases are fired by sudden compression in a cylinder, according to Nernst's suggestion. Photographs have been taken on a rapidly moving film of the flames produced by adiabatic compression. The values found are lower than those given by the first method, as was to be expected from the high pressures at which the gases are fired. These experiments are being continued.

Professor Dixon has also continued his experiments on the velocity of sound in different gases heated in a long tube.

Apart from the new investigations dealt with in the Notes, much preparatory work has been done by many of the members. Thus Professor Dalby has refitted the engine—the subject of his experiments—with electric ignition, and arranged the end so as to take a new optical indicator; Professor Bone has made preparations to extend his well-known experiments to explosions and combustions where oxygen is present in excess; Professor Coker has improved his apparatus for studying wall-temperature change; Professor Burstall, in conjunction with Professor Hopkinson, has made comparisons between a good mechanical indicator and the Hopkinson optical indicator; Watson, Callendar, and Dalby have devoted much study to the improvement of the diaphragm optical indicator; and Hopkinson and Clerk have improved the operation of their piston optical indicators.

In this Report the sequence of the first Report will be followed as far as possible, so that the effect of the year's work will be readily apparent.

Measurement of the Internal Energy or Specific Heat of Gas at High Temperatures.

No new high-temperature experiments on 'Volumetric Heat' have been published, but attention has been devoted to the lower end of the scale, as Regnault's and other standard results were shown last year to be in need of revision. This was necessary in order to clear the ground for high-temperature work.

(1) *Constant Pressure Experiments up to* 100° *C.*

It was stated in the first Report that the results of Regnault for the specific heat of air at ordinary temperatures, which have hitherto been accepted as correct, were materially lower than those obtained by some more recent observers. Among these latter researches the most important were perhaps those of Mr. Swann,[2] the results of whose experiments, which had not then been published, were communicated to the Committee by Professor Callendar, and gave values about 2 per cent.

[1] Dixon and Coward, 'The Ignition Temperature of Gases,' *Jour. Chem. Soc.*, 1909.

[2] 'The specific heats of air and carbon dioxide at atmospheric pressure by the continuous electrical method at 20° C. and 100° C.,' by W. F. G. Swann, A.R.C.S., B.Sc., *Proc. Royal Soc.*, Series A, vol. lxxxii. 1909.

higher than those of Regnault. Mr. Swann's results have now been published, and he has supplied the Committee with a complete copy of his paper. The method employed by him had previously been used by Professor Callendar for determining the specific heat of superheated steam. A current of the gas is passed over an electrical heater, the energy supplied to which can be accurately measured, and the temperature of the gas is measured before and after passing the heater by means of platinum thermometers. The rise of temperature, which amounted to about 5° C., can be measured correct to 0·001° C., and an at least equal degree of accuracy is obtainable in the measurement of energy supplied. A correction of the order of 10 per cent. of the total supply of heat has, however, to be applied for the loss of heat from the gas as it passes to the thermometer. It is assumed that with a given inflow and outflow temperature of the gas this loss of heat is independent of the rate of flow, and its amount is determined by experiments at different rates of flow.

It will be remembered that a correction, amounting to about 5 per cent., was applied in Regnault's experiments for the flow of heat by conduction along the substance of the pipe which connected his heater with his calorimeter. Regnault assumed that with a given temperature difference this correction was independent of the rate of flow of gas. It was pointed out by Professor Callendar that this assumption could not be justified, and that it would lead to too low a value of the volumetric heat.

The corrections involved in the methods employed by Swann have been fully discussed by the author, and also by Callendar. They appear to admit of determination with an order of accuracy approaching 1 in 1000 in the result. On this account, and because of the close agreement of Swann's results with those obtained by Joly, the Committee consider that there is now little doubt that Regnault's figures were too low, and that the volumetric heat of air at 100° C. may be taken as being within 1 per cent. of 5·0 calories per gm. molecule, or 19·8 foot lb. per cubic foot.

They have come to this conclusion with the less difficulty because to a great extent they have Regnault's own authority for it. He appears to have been fully aware of the uncertainty introduced into his results by the heat-flow along the connecting pipe; he discusses it in the same way as Callendar and Swann, and arrives at the same conclusion, that is, that it would be in such a direction as to make his results too low. The passage of his original paper in which he deals with this matter is of very considerable interest, both historically and in connection with the work of the Committee, and they have therefore reproduced it in full in Appendix A.

For the volumetric heat of CO_2 the Committee also feel justified in adopting Swann's values as correct to within 1 per cent. They are as follows:—

	At 20° *C.*	*At* 100° *C.*
Specific heat at constant pressure	0·202	0·221
Volumetric heat:—		
Cals. per gm. molecule [1]	6·93	7·76
Foot lb. per cubic foot	27·4	30·7

[1] Taken as 44 grammes.

(2) *Clerk's Experiments.*

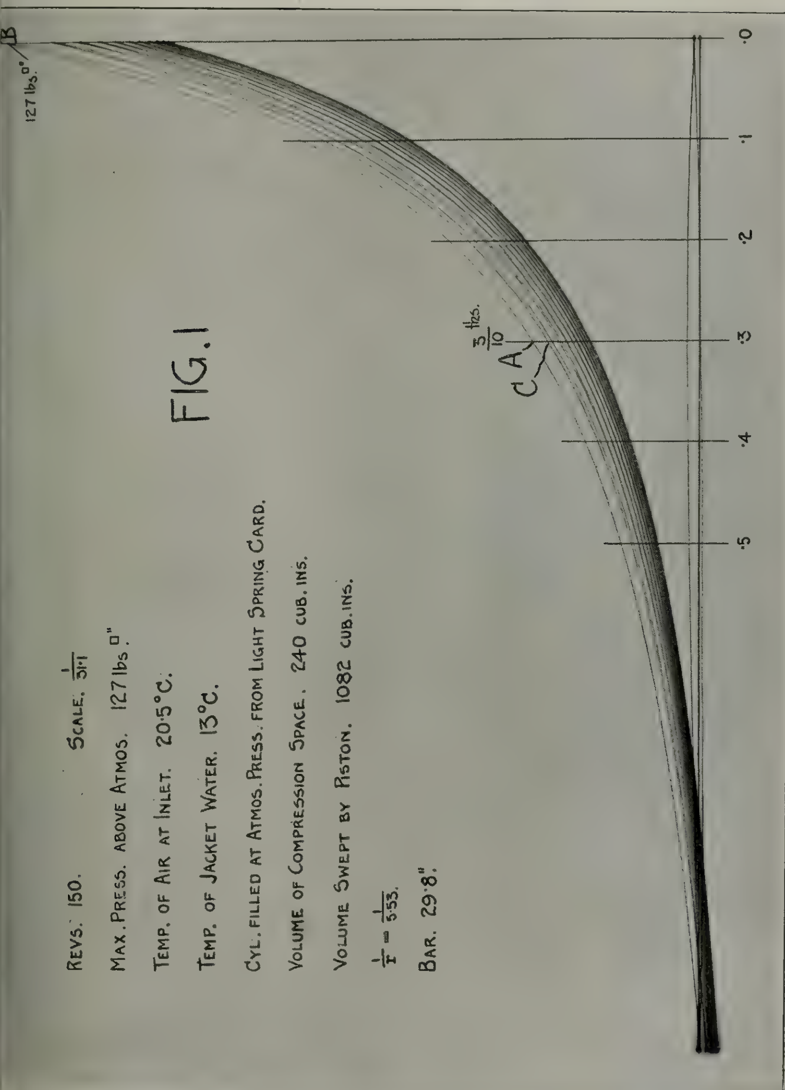
In the first Report it was pointed out that the values of the volumetric heat of gas-engine mixture obtained by Dugald Clerk by the compression and expansion of gas heated by combustion were (at a temperature of 1000° C.) about 10 per cent. higher than the corresponding values given by Holborn and Henning's experiments at constant pressure. Callendar expressed an opinion that the constant-pressure methods of determining specific heat were subject to systematic errors which would tend to make the results too low. This view has received further confirmation in the publication of Swann's work, to which reference was made in the last section; for Regnault's experiments were of the same character as those of Holborn and Henning, and any error of defect in his values might be expected to be of even greater magnitude in their experiments. On the other hand, Hopkinson gave reasons for supposing that Dugald Clerk's values were too high because of a difficulty in determining the division of heat loss between the compression and expansion lines. In support of this view Hopkinson stated that he had found that when cold air was compressed and expanded in a gas-engine driven by an electric motor the values of the volumetric heat deduced by Clerk's method from the compression and expansion lines were too high, and that the air took in heat during the first half of the expansion stroke, though its mean temperature was above that of the walls.

This point has been made the subject of detailed experiments by Dugald Clerk, who communicated a preliminary account to the Committee in Note No. 11. His experiments were made on the 'R' engine of the Institution of Civil Engineers' Tests,[1] of 9 inches diameter and 17 inches stroke, which was driven by an electric motor. The exhaust valve of the engine was permanently closed during the experiments, and communication was made with a large reservoir containing dry air by means of the charge inlet valve, which was held partially open until the desired engine speed was attained, when the valve was tripped and acted on by the usual cam, so as to take an air charge into the cylinder. The trip gear was so arranged that after one full opening and closing the valve was held closed during the experiments so that the air thus trapped in the cylinder was alternately compressed and expanded. In this respect Clerk's arrangements differed from Hopkinson's, who kept both inlet and exhaust valves working continuously in the ordinary way, thus taking in a fresh charge of air at every other revolution, compressing and expanding it once and then discharging it. An optical indicator was used to take the diagrams, one of which is reproduced in Fig. 1.[2]

An analysis of the last three-tenths of the first compression line and the first three-tenths of the first expansion line (AB and BC on the figure) by Clerk's method, in which the heat loss is treated as the same in compression and expansion, subject to an allowance for the higher temperature in the former, gave as the value of the volumetric heat of air 20·9 foot lb. per cubic foot, or 5·28 calories per gm. molecule. This was the mean of six cards, three of which were taken at a speed of 120 r.p.m. and three at 180 r.p.m.; the maximum value found was 21·1 and the minimum 20·5. The mean temperature on the expansion line was about

[1] *Minutes of Proceedings Inst.C.E.*, vol. clxiii. p. 288.

[2] The particular diagram shown in Fig. 1 belongs to a later set of experiments.



Illustrating the Second Report on Gaseous Explosions.

170° C. and the value of $\bar{C}$ obtained by extrapolating slightly from Swann's results would be 20·16 at this temperature and at atmospheric pressure. Unless, therefore, the difference in density gives rise to a greater difference in the volumetric heat than seems at all probable, Clerk's value is about 3 per cent. too high.

Clerk then went on to calculate from the diagram the actual heat loss on the compression and on the expansion stroke, assuming the true value of the volumetric heat to be 20. Comparing the heat loss in the last three-tenths of the compression (AB) and the first three-tenths of the expansion (BC), he found that they were in the ratio of about 3 to 1, whereas the mean temperature on compression was only about 11 per cent. greater than over the corresponding range in expansion. Clerk further found that the heat loss from 0·1 to 0·4 on the expansion stroke was practically *nil*, while on the corresponding part of the compression stroke it amounted to about 7 per cent. of the work done on the gas.

Commenting on these results, Clerk says: 'The experiments show that the gas does not on the whole gain heat during the first half of the expansion stroke, as was found by Hopkinson.[1] But they do show that for some reason the heat loss is divided very unequally between the compression and expansion strokes. The proportion varies from point to point of the stroke, and also varies largely with the temperature of the walls, but for the inner one-tenth and the first three-tenths of the stroke the compression heat loss appears to be about three times the expansion heat loss.

'From this it follows that Hopkinson was correct in his expectation that the specific heat of air determined by division of heat loss in proportion to mean temperature would be too high. The experiments show that this method of division leads to a value about 3 per cent. higher than the true value.'

Clerk also finds from these experiments that the greater part of the heat loss was incurred at the inner tenth of the stroke during compression and expansion at the higher temperature and density; 80 per cent. of the loss on the three-tenths was due to the inner tenth. The loss on the compression line from 0·4 to 0·1 of the stroke was small, and that on the expansion line was less. Calculating $\bar{C}$ as the mean value on these lines, the value is 20·7 foot lb. per cubic foot. The mean temperature in this part of the diagram was 120° C.

In view of these experiments on the compression and expansion of cold air, the Committee consider that the division of heat loss in the high temperature compressions on which Clerk's values of the volumetric heats are based may require some revision, and that these values may on this account be rather too high. The results given by air (as to ratio of heat loss between compression and expansion lines) at temperatures of the order 200° C. may, however, not be quantitatively applicable to gases cooling at the high temperature of 1000° C. It will be necessary to experiment further on high temperature compression before the amount of the correction necessary on this account can be decided. Clerk has

[1] The gain of heat found by Hopkinson may have been due to the fact that he did not trap a single charge, but continually compressed and expanded fresh charges, in consequence of which the temperature of the cylinder walls, and especially of the face of the piston, must have been materially higher than in Clerk's experiments.

made arrangements to continue the work on these lines, and hopes to be able to carry his explosion experiments to about 3000° C. by a modified method.

Clerk determined the leakage of the piston by two methods and found that it did not exceed 0·3 per cent. per stroke, so that error by leakage is negligible.

Hopkinson's suggestion that heat may be absorbed by a body of air whose mean temperature is higher than that of the walls enclosing it has been supposed by some to be impossible. If, however, the case be put in the following way it will be readily admitted that his explanation is quite possible.

Referring to Fig. 2, which is a diagrammatic section of a gas-engine cylinder having a very elongated compression space, if it be assumed that air be compressed within the cylinder until the piston is full in, as shown in the dotted position, then the mean temperature may rise to, say, 240° C. as a mean throughout the whole space, but the air at the extreme end of that space may be cooled down nearly to the wall temperature, assumed to be 16° C.

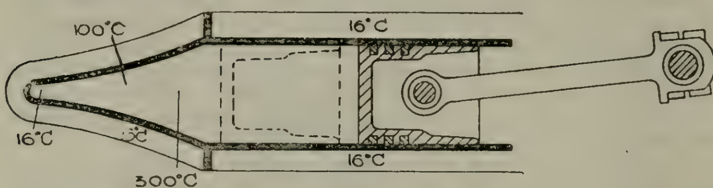


FIG. 2.

The temperature will thus range from nearly 16° C. at the small end of the cone to perhaps 300° C. in the open part of the compression chamber. Such a disposition may be made to produce a mean temperature throughout the whole compression chamber of 240° C. If the air be now expanded by moving the piston from the dotted position to the full-line position, it is obvious that the temperature of the air, which has been reduced to 16° C. by contact with the walls, will fall below that temperature, and so heat may be added to the air at the extreme end while heat is still being lost to the cylinder by the air near the piston. Many gas-engine constructions have narrow spaces, and the engine 'R' above its inlet valve has such a space, so that the temperature throughout, even during compression and expansion, may be very unequal.

Although the unequal division of heat-flow between compression and expansion lines must be accepted as a fact, the Committee are not yet satisfied as to the explanation. The view put forward by Clerk, when discussing the possibility of an error from this source in his original paper,[1] was that the difference, if any, between the heat-flow during expansion and during compression was to be ascribed to a rise in the temperature of the surface of the metal or of a film adhering thereto. He expressed the opinion that any difference so caused could not be great on account of the small possible variation in temperature of the metal surface. Hopkinson's suggestion, on the other hand, was based on the possibility of

[1] *Proc. Roy. Soc.*, Series A, vol. lxxvii. 1906.

large variations of temperature in the gas, and referred the change of heat-flow not to the metal surface, whose temperature (he thought) might for this purpose be supposed to be constant, but to changes in the temperature gradient in the layer of gas close to the walls. The controlling influence of the condition of the surface layer on the rate of heat-flow from the gas appears in many experiments. In a gaseous explosion in a closed vessel, for example, the flow of heat from the gas to the walls is at first intensely rapid, for the hot flame is brought into immediate contact with the cold wall and the heat is drawn from the still hot surface layer, and has not very far to travel. As time goes on, however, this layer becomes cooled down, and serves as a jacket resisting flow of heat from the hotter core within. Study of the curve of cooling after explosion in a closed vessel shows that the rate of fall of temperature diminishes in much greater proportion than the temperature itself, and the same thing was shown by Hopkinson's experiments with a recording calorimeter, in which the rate of heat-flow was directly measured and found to vary nearly inversely as the square root of the time elapsed.[1]

The basis of Clerk's method is a comparison of volume and pressure changes in the rapid compression of a gas in a closed cylinder. In adiabatic compression the relation between these two quantities is—

$$PV^{\gamma} = \text{a constant},$$

and the mean value of the volumetric heat over the range of compression is $\frac{R}{\gamma-1}$, where R is the gas constant and equal to 7·75 foot lb. per cubic foot or 1·96 calories per gm. molecule. The value of γ for true adiabatic compression is deduced from the actual indicator diagram by making corrections for heat loss in the manner to which reference has already been made. Another method of obtaining γ is to find the relation between corresponding pressure and temperature changes in rapid compression. For adiabatic compression this relation is of the form

$$\theta \propto P^{\frac{\gamma-1}{\gamma}}$$

where θ is the absolute temperature. It has been applied for small ranges of temperature by Lummer and Pringsheim, and also by Makower, who suddenly opened to the atmosphere a large glass globe, containing air at a pressure of a few centimetres of mercury above atmosphere, and measured the resulting fall of temperature at the centre of the globe by means of a platinum thermometer. He obtained in this way the value 19·3 foot lb. per cubic foot or 4·9 calories per gm. molecule for the volumetric heat of air at 20° C., which is certainly within 2 per cent. of the truth, without making any correction for heat loss from the air at the centre of the globe where the temperature was measured.

Hopkinson has commenced experiments, described in Note No. 13, with the object of applying a similar method to the compression of air in a gas-engine cylinder. The engine is motored round, taking in a charge of air at every other revolution, compressing it, expanding it, and exhausting it in the usual way. A fine platinum wire at the centre of the combustion space of the engine measures the temperature of the air at

[1] *Proc. Roy. Soc.*, Series A, vol. lxxix. p. 138.

that point, and simultaneous measurements of the pressure at the beginning and end of compression are also made. A small correction for time-lag in the wire has to be applied; this amounts at a speed of 250 revs. per minute to about 6° C. at the completion of suction, and is negligible at the top of compression. The value of the volumetric heat calculated from the pressures and temperatures at these two points, on the assumption that the compression was adiabatic and that γ was constant, is 20·33 foot. lb. per cubic foot, the values in different experiments ranging from 19·76 to 20·95. The true value, according to Swann, for the range of temperature employed (20° to 270°) should be 20·1. It would appear, therefore, that the compression at the centre of the combustion space in an engine of this size (the diameter was 7 inches and the stroke 15 inches) is very nearly adiabatic, and there is reason to suppose that the method may yield good results when applied to higher temperatures. The experiments were done at various speeds, ranging from 60 to 250 r.p.m., and the fact that the values obtained at 60 r.p.m. are not systematically greater than those at higher speeds is further evidence that the loss of heat is small. The method has the advantage that it is independent of leakage. Hopkinson found that in this engine at the top of compression the temperature of the air at a distance of half a centimetre from the wall was about 30° less than in the centre. At points nearer to the wall, that is, within 1 mm., the temperature fell off very rapidly; it was still, however, decidedly above that of the wall at a distance of only $\frac{1}{10}$mm. He is continuing his experiments with a view to giving a complete account of the temperature distribution and elucidating more completely the phenomena of heat-flow. The general result, so far as he has gone, would appear to be that the layer of air in which the temperature gradients are considerable is extremely thin. It may, in fact, be difficult to decide precisely what is the nature of the film which determines the heat-flow. Once in solid metal it is quite certain that the temperature variations are extremely slight, and cannot be such as materially to affect heat-flow. On the other hand, the temperature of the air a fraction of a millimetre away from the wall is very much higher than that of the metal and approximates to the mean temperature of the gas. It is the temperature gradients in the composite layer of matter, partly air and partly solid or oil film, between these points which finally determine the heat-flow. It is possible that Clerk, who regards the solid and adherent film [1] as the seat of the temperature changes, and Hopkinson, who ascribes the action to a thin layer of air, are really dealing with the same thing from opposite points of view.

(3) *Explosion Experiments.*

Much light has been thrown on the chemical processes in such explosions as occur in the gas-engine by a very complete study made by Dr. Watson of the thermal and combustion efficiency in a petrol motor.[2]

[1] In later experiments on the compression and expansion of air in an 'R' engine, with a very large flow of water through the jacket, Clerk finds that the heat-flow on compression and expansion becomes nearly proportional to relative temperatures. This appears in Clerk's view to support the hypothesis of an adherent film which in some conditions of experiments accumulates heat and rises in temperature.

[2] *Proc. Inst. Auto. Eng.,* May 1909.

Such a motor on account of its high speed is well suited for the investigation of this question; in some of Dr. Watson's experiments as little as $\frac{1}{50}$ of a second elapsed between the ignition of the mixture of petrol and air and the discharge of exhaust gases. The most important part of Watson's work from the point of view of the Committee is the simultaneous measurement which he has made of the quantities of air and of petrol taken into the engine and of the chemical composition of the exhaust gases.

Several observers have found that even when the combustion in the petrol engine is apparently perfect, there being some excess of oxygen and no carbon monoxide or hydrogen in the exhaust, the ratio of hydrogen to carbon in the exhaust gases is considerably greater than in the petrol used, showing that even in this case there must be some incomplete combustion.[1] The very complete set of analyses taken by Dr. Watson, of which he was good enough to give full particulars to the Committee in Note No. 7, before his paper was published, bear out this observation, and show that the discrepancy between the composition of the exhaust gases determined in this way and that of the petrol is not due to errors of experiment.

Some evidence as to the cause of the discrepancy is furnished by some experiments of Hopkinson, who found that by exploding the residue of the exhaust, after absorbing CO and H, with electrolytic gas a considerable further yield of Co_2, amounting to nearly 5 per cent., was obtained. Hopkinson also found that the residual combustible gas revealed in this way was soluble in water, which points to the possibility that it may be an aldehyde or possibly acetylene. It is known that in the combustion of hydrocarbons, such as petrol, with insufficient oxygen, considerable quantities of aldehyde are formed, but so far as the Committee are aware the question has not been fully investigated where sufficient oxygen is present to burn the petrol. It is at least possible that the effect may be due to deficient vaporisation or incomplete mixture in the combustion as it occurs in the petrol motor, and that it would not happen if the petrol were completely converted into vapour, and that vapour sufficiently intimately mixed with the air before combustion took place. Prof. Bone, however, considers that the combustion of a hydrocarbon with insufficient oxygen is not different as to chemical actions from combustion with excess oxygen, and he dissents from the view that the effect observed may be due to deficient vaporisation or incomplete mixture. The question is one well worthy of the attention of those chemists who are engaged in the study of the combustion of hydrocarbons. Whatever the explanation, the practical result established by these experiments of Watson and Hopkinson is that the petrol is rarely, if ever, completely burnt in a motor fed by the ordinary types of carburettor, even when there is apparently a considerable excess of oxygen.

Neither Watson's nor Hopkinson's experiments, which are in full agreement with one another, suggest that the incomplete combustion occurring in the petrol motor is conditioned in any way by the speed of revolution. It is probable, therefore, that it is not incomplete combustion of the kind contemplated by the Committee and referred to in their

[1] Hopkinson, *Engineering*, August 9, 1907; Clerk, *Proc. Inst. Auto. Eng.*, December 1907; Hopkinson, *Proc. Inst. Auto. Eng.*, February 1909.

first Report, such as may be caused by the action of the cold walls of an explosion vessel in which a truly homogeneous mixture is exploded.[1]

Some light is thrown on this question by some experiments made by Dugald Clerk during the year under review, who has exploded mixtures

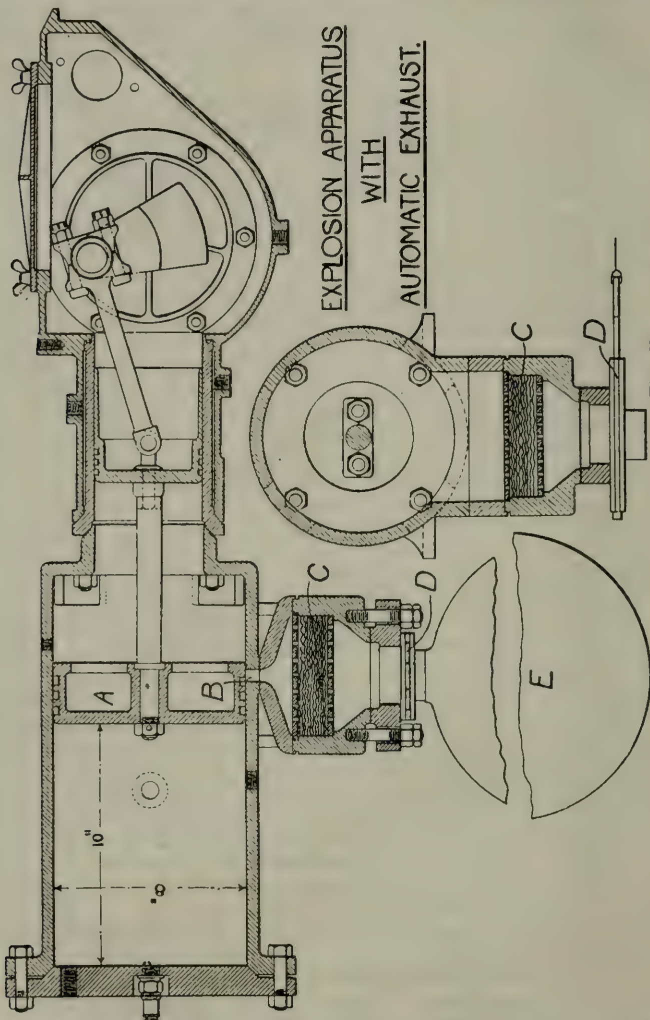


FIG. 3.

of coal-gas and air in an apparatus (shown in Fig. 3) consisting of a cylinder containing a piston A, which piston could overrun a port B at

[1] Prof. Bone writes: 'I am not in the least surprised that Dr. Watson has obtained evidence of some disappearance of carbon (as a soluble product) in his

the end of the stroke. The cylinder was charged with a mixture of gas and air, the piston being placed so that the port was closed, and sufficient time was allowed for complete diffusion to take place. The mixture, which was at atmospheric pressure and temperature, was then fired, the pressure generated forced out the piston, which opened the port at a period varying from 0·11 to 0·23 second from the moment of explosion, thus liberating the gases. The gases escaped through the port and through a passage packed with cold wire gauze C by way of a small slide-valve D into a collapsed gas-bag E. The gauze checked any chemical action going on in the gases, which were subsequently removed from the bag into which they had been exhausted and analysed. In each of eight experiments, three of which were made with a mixture of 1 volume of coal gas to 7 of air, and five with a 1 in 10 mixture, a certain proportion of unburnt fuel was found in the exhaust. The quantity of carbon ranged from 2 to 4·3 per cent. by volume and the quantity of hydrogen from 0·8 to 3·7 per cent. by volume. These experiments seem to prove that from some cause combustion continues even in the explosion of a strong mixture for some little time after the attainment of maximum pressure.

In the petrol motor as ordinarily used the air is insufficient to burn the petrol completely. Under these conditions the efficiency of the engine, reckoned on the actual consumption of petrol, is of course much reduced, since the exhaust contains CO and other substances of considerable heating value. Hopkinson and Morse, however, pointed out two years ago[1] that if the efficiency were calculated on the heating value of the chemical changes which actually took place in the engine, it remained nearly constant over a wide range of mixture strength, as was to be expected from theory. The effect of mixture strength on the efficiency of a petrol motor has been exhaustively investigated by Watson during the past year. Some of his results are given in the following table:—

$\frac{\text{Air}}{\text{Petrol}}$ by Weight	Indicated Thermal Efficiency calculated on		
	Whole Calorific Value of Fuel	Calorific Value corresponding to the Chemical Changes which actually take place	Percentage of Heat of Fuel liberated
14	·248	·251	99
13	·235	·264	89
12	·220	·278	79
11	·204	·287	71
10	·185	·289	64

Fig. 4 gives curves showing change of thermal efficiency with ratio of air and petrol by weight, beginning with a mixture having so little

experiments; indeed, I should have been rather surprised if he had not obtained such evidence. Some years ago, working on the combustion of dense hydrocarbons in a Diesel engine, I found a considerable "disappearance" of both carbon and hydrogen, which was at once explained when the water condensed from the exhaust gases was found to give very strong aldehydic reaction.'

[1] *Engineering*, August 9, 1907.

petrol as 1 part by weight to 19 parts by weight of air up to 1 part petrol to 10 parts air.

The efficiency rises from A to B and falls from B to D. The line C to E starting from the point C on BD gives the efficiencies calculated on the basis of the heat liberated during the chemical changes which actually occur. The efficiency rises from point A to point B, the lower efficiency at point A being due to slow inflammation of the mixture for the speed of the engine, so that burning is continued after the constant volume phase is passed. B is the point of maximum efficiency, but it does not appear to be the point of maximum chemical combination; the most complete chemical combination is found at the point C. The fall of efficiency is doubtless due to the continually increasing flame temperature between B and C, that is between a mixture of 1 part by weight of petrol to 17·3 parts of air and 1 part of petrol to 14 parts of air. The increasing flame temperature with the richer mixture increases the heat

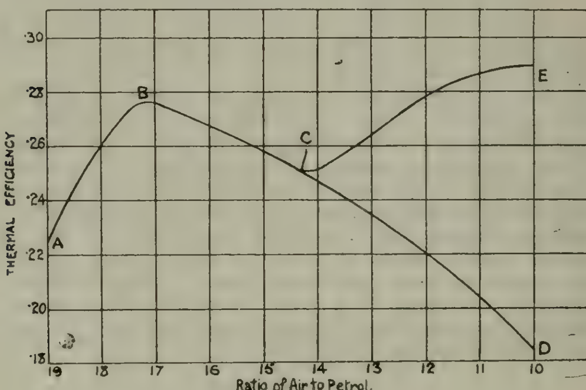


FIG. 4.

loss and also increases the mean specific heat of the gases over the range of the temperature used, and so efficiency is diminished from both causes. From C to D the petrol is in excess, and hence the flame temperature must on the whole be falling. At the point D a very large quantity, however, of the fuel is being discharged incompletely burned, as only 64 per cent. of the heat of the fuel is liberated. Calculating, however, the line CE, which is the line giving the thermal efficiency of the engine for the chemical action actually completed, it is somewhat surprising and interesting to find how greatly efficiency increases. With 1 of petrol to 10 of air it rises as high as 0·289. For these tests the air standard efficiency was 0.46, so that the efficiency ratio was 0·64—an extremely high efficiency for so small an engine.[1]

[1] The portion CE of the curve is calculated by deducting from the calorific value of the petrol the heat which would be liberated if the CO, H, and CH_4 in the exhaust were burnt to CO_2 and H_2O. There is some uncertainty in the result because there is undoubtedly some combustible matter in the exhaust which is not accounted for in the analyses. Moreover, in Dr. Watson's experiments the H and

This increase in efficiency is to be ascribed mainly to the reduction of flame temperature—much as in Dugald Clerk's super-compression experiments. A small increase is also to be expected from the increase of specific volume which occurs on explosion, and which may amount to as much as 10 per cent. volume in extreme cases. Although this volume change is insignificant compared with that occurring in explosives of solids like gunpowder and cordite, yet it should strictly be included in calculations of thermal efficiency. It tends to make the efficiency of a petrol engine rather greater than that of a gas-engine, in which the compression and heat supply per cubic foot are the same.

Radiation in Gaseous Explosions.

The importance of radiation in its bearing upon the calculation of volumetric heats from explosion pressures was pointed out in the first Report. It is probable that the loss of heat from this cause, or at any rate that part of it which occurs during the progress of the flame, is independent of the size or surface area of the vessel, and cannot therefore be allowed for by a comparison of vessels of different sizes. Any considerable amount of radiation of this character will seriously affect the values of the volumetric heat obtained by explosion experiments.

Hopkinson has been investigating this question, and has made some progress during the year. He gives some of his results in Note No. 10. It will be remembered that at the meeting of the British Association at Dublin he described the results of some experiments which he had made dealing with the effect upon explosion pressures of the nature of the surface of the vessel. He coated the inside of the explosion vessel with tinfoil, and compared the results of exploding identical mixtures, first with the tinfoil brightly polished, and, secondly, when it was covered with lamp-black. He found that the difference in maximum pressure was inappreciable, but that the rate of fall of pressure during cooling was considerably less with the bright lining than with the dark lining. This is in accordance with observations which have been made upon the effect of polishing the interior of the combustion space of a gas-engine, which has been found to result in a perceptible increase in mean pressure.

During the year Hopkinson and his pupils have been carrying out further investigations on this subject. The results described in the last paragraph have been fully confirmed, and direct bolometric measurements have also been made of the radiation in an explosion. For this purpose a small portion of the surface of the explosion vessel was covered with thin copper strip, and the rise of resistance of this strip during the explosion was recorded by means of a quick period reflecting galvanometer, a record of the pressure being taken at the same time. Comparative experiments were made first with the strip polished as highly

CH_4 were not directly measured, but were calculated by means of an empirical formula from the measured quantity of CO. Hopkinson and Morse worked out the heat developed by burning the oxygen present to CO, CO_2, and H_2O in the proportions found in the exhaust. The result obtained is rather different from that calculated by Watson's method, and this may account for the fact that Hopkinson found a smaller increase in efficiency with richness of charge than did Watson, though the observations on which his calculations were based were in good agreement with Watson's.

as possible; secondly, with it blackened over; and, thirdly, after it had been protected from direct contact with the flame by means of a plate of rock-salt fixed in front of it. It was found that the rate of rise of temperature of the blackened strip during combustion and the early stages of cooling greatly exceeded that of the polished strip, and that the difference between them was, roughly, the same as the rate of rise of temperature of the strip protected by rock-salt. It appeared that the amount of heat lost to the walls of the vessel by radiation up to the moment of maximum pressure was, with a 15-per-cent. mixture by volume of coal-gas and air giving a maximum temperature of 2150° C., of the order of 5 per cent. of the whole heat of combustion, and there was evidence that the radiation continued for some considerable time after maximum pressure, until the temperature of the gas had fallen to 1400° C. The experiments are not yet sufficiently advanced to give a quantitative basis for the correction of volumetric heats obtained by explosion experiments, but Hopkinson considers that they establish the fact of a material amount of radiation at the moment of maximum pressure and during the first stages of cooling.

Apart from their bearing on the determination of volumetric heats, these results, if fully confirmed and proved to be due to radiation and not to differences in roughness of surfaces or other secondary causes, will raise interesting questions as to the origin of the radiation and as to the state of the gas at the moment of maximum pressure. Comparing the two explosions, one with the bright lining and the other with the blackened lining, it seems to be established that the maximum pressure and the maximum temperature are the same; on the other hand, the experiment with the bolometer would seem to show that more heat has been lost in the one case than in the other; and therefore the energy of the gas enclosed in the bright lining is greater than that of the gas enclosed in the blackened lining, though the temperatures are the same. If this be the fact, there must be some want of equilibrium at this moment. Many chemists, including Bunsen and Professors Smithells and Dixon, have held the opinion that radiation from a gas, at any rate at temperatures such as can be obtained in an explosion, can only go on as a result of some sort of chemical or quasi-chemical action. According to this view, the want of equilibrium at the moment of maximum pressure must be due to incomplete combustion, and the continuing radiation after maximum pressure must be regarded as evidence of continued chemical action. This view as to the radiation from a gas is, however, not generally accepted, and the existence of radiation, therefore, cannot be regarded as conclusive evidence of continued combustion. If it be assumed that combustion is complete at the moment of maximum pressure or very shortly after it, then the want of equilibrium at this moment disclosed by the experiments must be ascribed to purely thermal causes. The most obvious explanation in such a case would be that the translation and vibrational energies of the molecules have not attained their equilibrium proportion. Since the temperatures in the two explosions with bright and blackened linings are the same, the translational energies, which alone determine temperatures, must also be the same. It is conceivable, however, that the energy represented by rotation or vibration of the molecules may be greater in one case than in the other.

The Measurement of Temperature.

(1) *Dissociation.*—In the first Report the importance of dissociation in connection with the gas scale of temperatures, which is the only scale at present available for explosion and gas-engine experiments, was pointed out, and a hope was expressed that an investigation of dissociation from this point of view might be undertaken by the National Physical Laboratory. The Committee are glad to be able to report that Dr. Glazebrook has given his sanction to such an investigation, which is now being carried on under the immediate superintendence of Dr. Harker, and that Dr. Glazebrook has shown his personal interest in this and the other matters engaging the attention of the Committee by joining them as a member.

The main object of the high temperature research work which is now in progress at the National Physical Laboratory is to obtain direct gas thermometer measurements up to 1700° C. or 1800° C., and it is to this object that Dr. Harker's efforts are being directed. On this inquiry the question as to the amount of dissociation present in the measuring gas has an important bearing, and may properly be included in high temperature research.

In order to have the facts in a form for discussion, Dr. Harker prepared a Note on the early work of dissociation, particularly the experiments of Grove and of Deville. This Note, No. 9, in view of its historical interest and its bearing on their work, the Committee have printed in full as Appendix B.

In view of the discrepancy which is apparent from the account given in this Appendix between the statements of Deville, on the one hand, and the recent work by Nernst and Wartenberg (which has been confirmed by Holt [1] on the other, as to the actual amount of dissociation in steam, CO and CO_2, particularly at low temperatures, it seemed of interest to ascertain if light might not be thrown on the question by a simple repetition of one or two of Deville's fundamental experiments.

Apparatus for this purpose has therefore been set up at the National Physical Laboratory, and was shown to the Committee on the occasion of their recent meeting at the Laboratory by invitation of Dr. Glazebrook. The methods and apparatus for the purification and heat treatment of the materials used in the preparation of very refractory vessels were also explained.

Sir William Preece was especially impressed with the necessity of repeating this early work, and accordingly the Committee welcome the installation of Deville's experiments under modern conditions and with modern appliances for the accurate measurement of temperature which were unavailable in Deville's time.[2]

(2) *Measurement of Pressure.*—It was pointed out in the first Report that the determination of the energy function depended upon the measurement of the temperature of the gas experimented with, and that two methods had been used. According to one method, the gases themselves which are within the engine cylinder or the explosion vessel are utilised as the thermometric fluid, and according to the other method the

[1] *Phil. Mag.*, May 1909.

[2] Professors Smithells and Bone doubt the relevance of experiments according to Deville's methods to the question of flame temperature, although they welcome the proposed experiments from the purely scientific point of view.

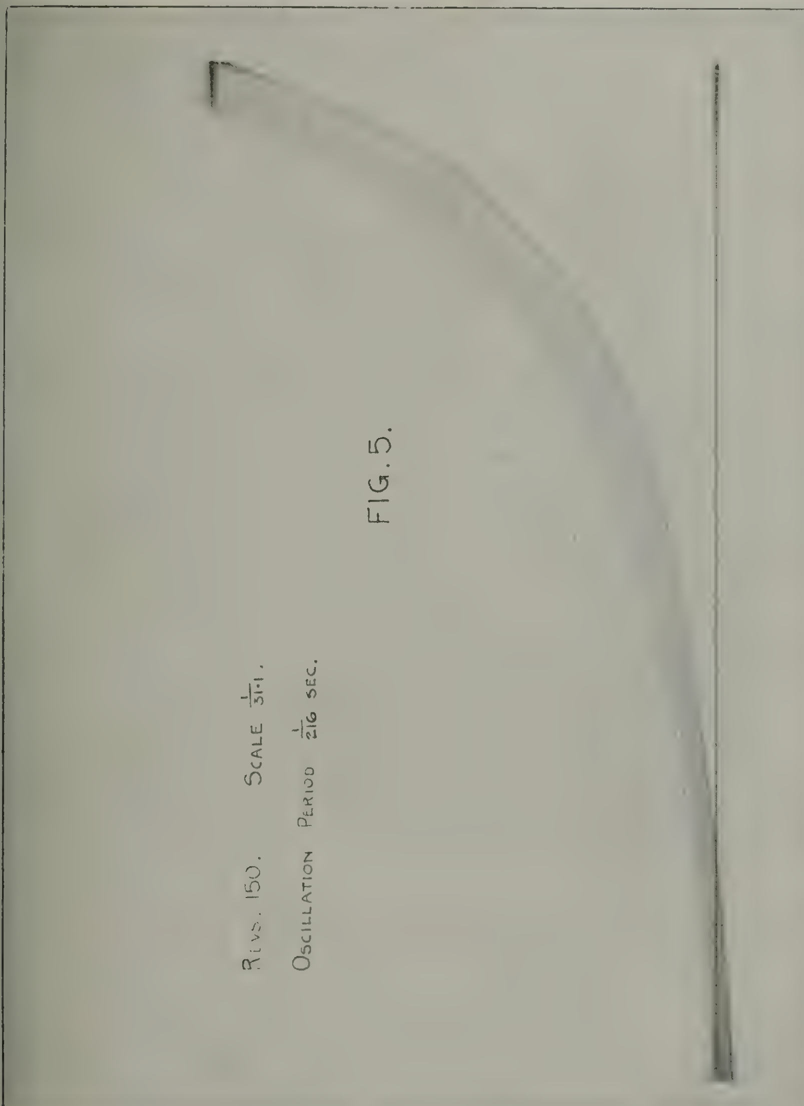
gas temperatures have been measured by a thermo-couple or a platinum resistance thermometer. The first method of measurement by pressure changes necessitates the use of accurate indicators. In gaseous explosions, pressures and temperatures before ignition are comparatively easily determined, but pressures after ignition are often difficult of determination for purely mechanical reasons. The Committee are of opinion that for accurate work in gaseous explosions optical indicators offer marked advantages, and they recommend that in all investigations depending upon the use of such indicators the oscillation period of the indicator should be given. In the piston indicators used by Clerk and Hopkinson this period is very easily determined. Fig. 5 is a photographic reproduction of an optical diagram taken by the Clerk indicator to determine the period of the instrument used for the experiments described in Note No. 11. Such diagrams are taken by causing the piston to strike against a stop before maximum pressure is reached. On the return of the piston after maximum compression or explosion it will be found that the expansion line shows an oscillation. From this oscillation the period of the indicator can be readily obtained. In this indicator the oscillation period is 1-216th of a second. With a light spring diagram shown in Fig. 6 the period is 1-108th of a second—double the period of the other. To make certain that the indicator registered the maximum pressure correctly, the piston was held up by a movable stop, so that the spring was compressed to within a few pounds of the maximum pressure. The first compression line is, therefore, omitted from a diagram produced in this way until nearing the maximum compression. The piston is then lifted from its stop whenever the pressure exceeds that put upon the spring by the stop, and the maximum pressure is indicated, avoiding the momentum effect which causes the piston to tend to overrun its true pressure. This is clearly shown in Fig. 7. A number of diagrams taken proved that the maximum pressure obtained with the stop in and the stop out was the same.

Oscillation period experiments and experiments with a stop are recommended to determine the accuracy and sensitiveness of piston-operated indicators. Careful comparisons made by Professor Burstall and Professor Hopkinson of the Hopkinson optical indicator and a specially selected Crosby mechanical indicator proved that the mechanical indicator gave maximum pressures differing considerably from the optical indicator, except when the ignition was very slow, though the mean pressure was nearly the same.

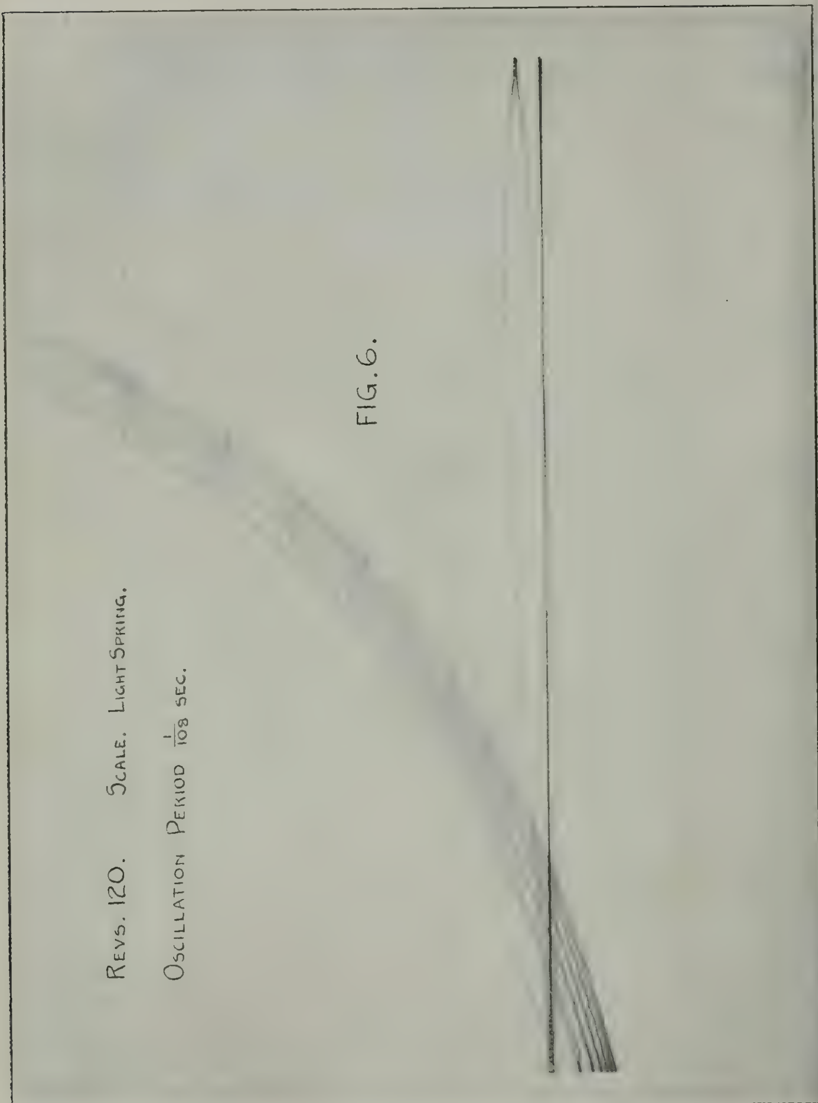
Fig. 8 shows a comparison of the two indicators which will be readily followed. Experiments made by Clerk with another mechanical indicator compared with a Clerk optical instrument showed deviations exceeding 5 per cent. in maximum pressures.

As showing the importance of temperature measurement in gaseous explosions, the Committee would refer to diagrams obtained by Callendar and Dalby, described in Dalby's Note No. 12. These diagrams showed a maximum temperature of 2500° C. of the gas and air mixture in a gas-engine cylinder—a temperature about 300° C. higher than any temperature obtained by ignition from atmospheric pressure. Professor Dalby is continuing his investigations, and many interesting points can be determined by his method of experimenting. The question of

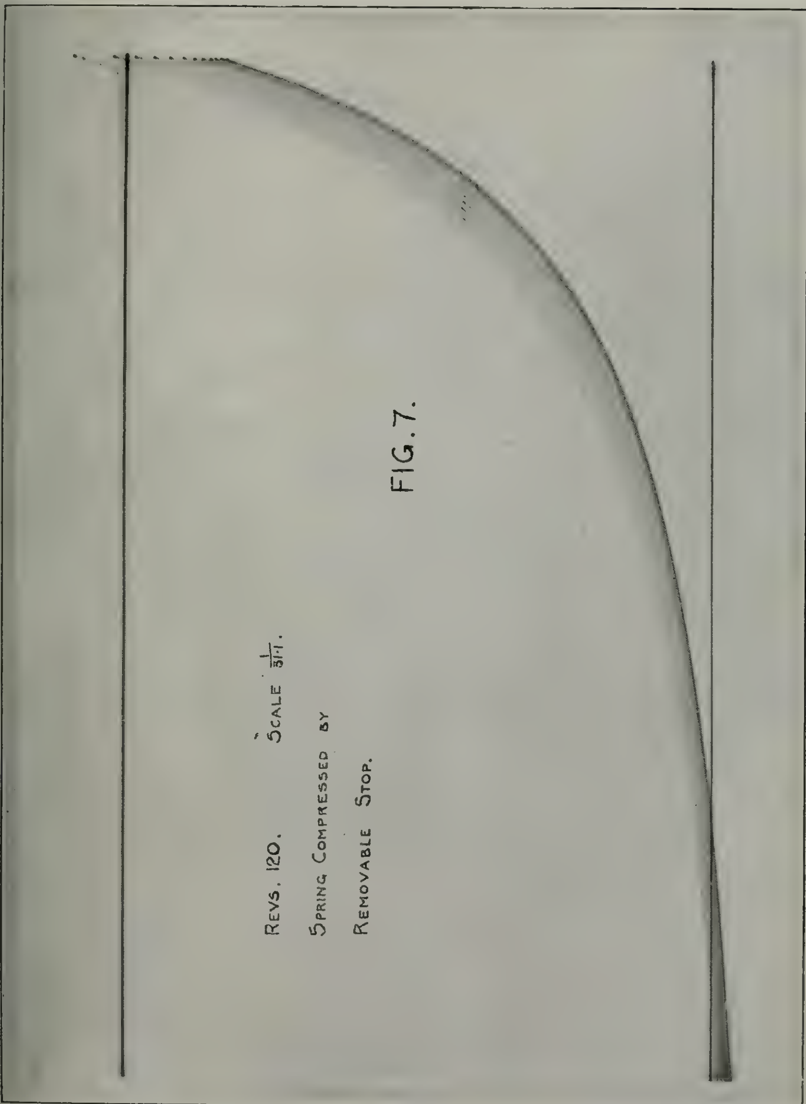
[1] See *Proc. Inst.M.E.*, July 1909.



Illustrating the Second Report on Gaseous Explosions.



Illustrating the Second Report on Gaseous Explosions.



Illustrating the Second Report on Gaseous Explosions.

dissociation is directly affected by the possibility of getting temperatures of 2500° C. with any gas and air mixture whatever.

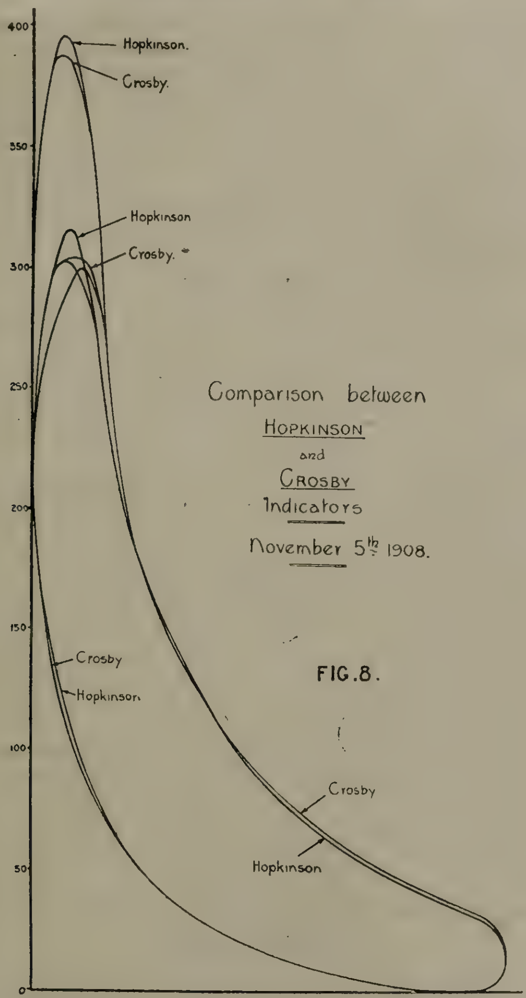


FIG. 8.

The Dublin grant has been carefully expended.

The Committee consider that their continued work will prove useful, and they therefore recommend that they be reappointed, and ask for a further grant of 100*l*.

APPENDIX A.

Regnault's Corrections.

Some explanation of Regnault's methods is necessary in order to make the following extract clear to those who are not familiar with his paper. The air was passed in a continuous stream through a pipe in a bath of heated oil and took the temperature of the oil. It then traversed a short pipe into a calorimeter, and in its passage through the calorimeter it took the temperature of the water therein. The rate of rise of temperature of the water in the calorimeter was observed over an interval varying in different experiments from five to forty minutes. It was assumed that the heat lost by the calorimeter to its surroundings and by conduction along the connecting pipe was such as to lower its temperature at the rate $\Delta\theta$ where:

$$\Delta\theta = A(\theta - t) + K.$$

is the temperature of the calorimeter, t that of the surrounding air, and A and K are constants independent of the rate of flow of air. The constant K represents the rate of flow of heat along the connecting pipe. A and K were determined by two observations of the change of temperature in the calorimeter which took place when the air current was stopped during two periods of ten minutes which immediately preceded and followed the experiment with air flowing.

The correction $\Delta\theta$ to be applied at each instant during the experiment to the observed rate of rise in θ was then calculated from the observed values of θ and t.

Regnault tested the correctness of the above assumption by making a series of determinations of the specific heat of air with currents of different velocity. He found that the apparent specific heat was practically constant over a wide range, extending from 10 grammes per minute to 30 grammes per minute. If the rate of flow were outside this range the apparent specific heat was less. In the case of the slower currents this was doubtless due to an error in the correction. The faster currents gave wrong values because the air had not time to take up the temperature of the oil-bath and of the calorimeter respectively.

There is a good illustration of Regnault's apparatus in Haber's 'Thermodynamics of Technical Gas Reactions,' p. 212.

Mémoires de l'Académie des Sciences de l'Institut Impérial de France, tome xxvi., p. 83.

On peut conclure de ces expériences que la formule

$$\Delta\theta = A(\theta - t) + K$$

dont les constantes ont été calculées, pour chaque expérience, d'après les éléments observés pendant la première et la dernière période, peut être employée, avec toute confiance, pour calculer les effets produits par les causes perturbatrices pendant le temps où le courant gazeux traverse l'appareil. Il est nécessaire, néanmoins, de faire sous ce rapport une réserve, car il se présente ici une cause d'incertitude que j'ai vainement cherché à éliminer, et dont je n'ai pas réussi à calculer les effets avec précision. Pendant la première et la dernière période de l'expérience, on observe les variations de température sous l'influence

du milieu ambiant et de la chaleur qui lui arrive par conductibilité, suivant l'ajutage qui le relie au bain d'huile. La première de ces causes agit d'une manière parfaitement semblable lorsque l'appareil est parcouru par le courant gazeux; mais il n'en est pas de même de la seconde. En effet, quand le gaz ne passe pas dans le calorimètre, l'une des extrémités de l'ajutage est à la température du bain d'huile, tandis que la température de la seconde extrémité doit se rapprocher de celle du calorimètre; le flux calorifique a lieu par suite de cette différence de température. Quand le gaz traverse l'appareil toute la petite tubulure en cuivre de l'ajutage est à la température du gaz entrant, c'est-à-dire à la température du bain d'huile, et l'excès de la quantité de chaleur qu'elle possède à un moment quelconque, relativement au premier cas, lui est nécessairement fourni par le courant gazeux, qui doit subir, par ce fait, un léger abaissement de température. On ne peut donc pas admettre que la valeur de K soit la même dans les deux cas. Lorsque le courant gazeux est rapide, la perte de chaleur que le gaz subit par cette cause doit être extrêmement petite, car le gaz n'a à fournir que la déperdition de chaleur que la tubulure éprouve à travers le petit bouchon, qui est très mauvais conducteur de la chaleur. Mais quand le courant gazeux est lent, cette perte n'est probablement pas négligeable, et c'est à cette cause qu'il faut attribuer en grande partie, la différence que l'on observe entre les valeurs de la chaleur spécifique, suivant qu'on la détermine avec un courant gazeux rapide ou avec un courant lent.

Il est certain que cette cause doit rendre la chaleur spécifique trop faible; mais je n'ai trouvé aucun moyen qui permet d'évaluer, même approximativement, l'importance de cette erreur. La disposition que j'ai donnée à l'ajutage avait pour effet de la rendre aussi petite que possible, et je pense que l'on peut conclure que entre les limites de vitesse du courant gazeux que j'ai employées dans les expériences définitives, l'erreur est complètement négligeable; car, autrement, la valeur de la chaleur spécifique d'un même gaz ne resterait pas sensiblement constante quand on fait varier considérablement sa vitesse d'écoulement, en restant toutefois entre les limites indiquées.

APPENDIX B.

Deville's Experiments on the Dissociation of Gases.

By Dr. J. A. Harker.

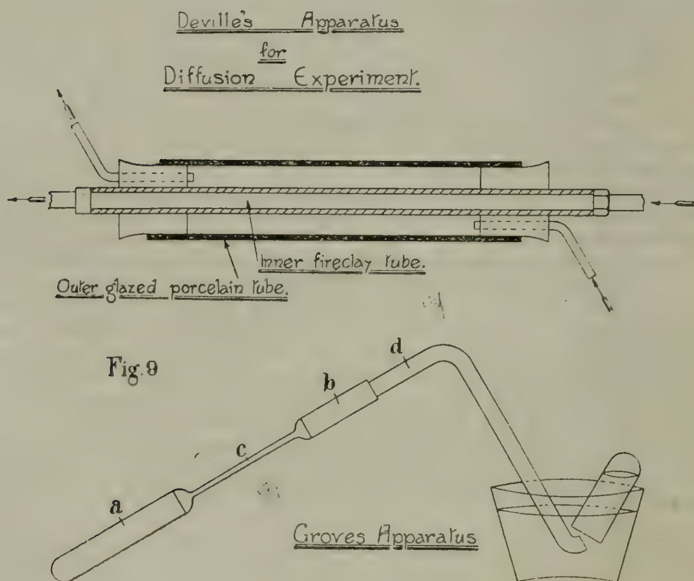
Introduction.—The importance of the *rôle* of gaseous dissociation in the phenomena which it is the business of the Committee to study led me to look up the original papers on the subject, particularly the work of Henri Sainte-Claire Deville. In view of the fact that there appears to be no adequate account in English of these experiments, which seem to occupy a unique position in the literature, a Note dealing with them would not seem inappropriate.

Deville appears to have commenced his experiments on this subject about 1851, his first work being a repetition of the celebrated experiments of Grove, which formed the subject of his Bakerian Lecture in 1847. Grove discussed the theory of the decomposition of water by heat, and seems to have had clear views as to what we now call

'dissociation,' though this term appears to have been first used by Deville in 1857.

One of his most interesting experiments Grove describes as follows[1]:—

'I was now anxious to produce a continuous development of mixed gas from water subjected to heat alone . . . and for this purpose the apparatus shown in Fig. 9 was constructed; *a* and *b* are two silver tubes 4 inches long and 0·3 inch diameter; they are joined by caps to a platinum tube, *c*, formed of a wire one-eighth of an inch in diameter, drilled throughout its length with a drill the size of a large pin; *a* is closed at



the extremity, and to *b* is fitted . . . the bent glass tube *d*. The whole is filled with prepared water, and having expelled the air from *a* by heat, the extremity of the glass tube is placed in a capsule of simmering water. Heat is now applied by a spirit lamp, first to *b*, then to *a*, until the whole boils; as soon as ebullition takes place, the flame of an oxy-hydrogen blowpipe is made to play upon the middle part of the platinum tube, *c*, and when this has reached a high point of ignition, which should be as near the fusing-point of platinum as practicable, gas is given off, which mixed with steam very soon fills the whole apparatus and bubbles up from the open extremity either into the air or into a gas collector. . . . I experienced a feeling of great gratification when, on applying a match to one of the bubbles which were ascending it gave

[1] *Phil. Trans.*, 1847-48, p. 12.

a sharp detonation. I collected and analysed some of it: it was 0·7 oxyhydrogen gas, the residue nitrogen, with a trace of oxygen.'

This experiment, and another one of Grove's, in which the decomposition of water was produced by dropping molten platinum into it, seemed to have served as the starting-point of Deville's experiments.

Deville published many of his results for the first time in two lectures delivered before the Paris Chemical Society on March 18 and April 1, 1864,[1] though much of his work had been done considerably earlier. The papers do not appear in the ordinary publications of the Society, but in a supplementary set of volumes of 'Leçons,' which seem to be comparatively rare, neither the Royal Society's nor the Chemical Society's libraries possessing a copy.

Deville appears to have realised the necessity for removing the dissociated products from further reaction, and in his experiments three methods were employed for the separation of the dissociated material from the unaltered gas, viz.:—

(1) By means of diffusion.
(2) By admixture with an inert gas.
(3) By very rapid cooling from a high temperature.

Preliminary Diffusion Experiments.—Before proceeding to describe the first experiments made by the diffusion method it will be well to mention some results obtained by Deville on the flow of gases through porous walls at ordinary temperatures, as they have considerable bearing on the later experiments.

(1) If a fairly rapid current of hydrogen be passed into a tube of unglazed porous ware, and thence to a collecting vessel, it is found that instead of hydrogen practically pure air is collected. Analyses gave the following as an average composition:—

Oxygen	21
Nitrogen	79
Hydrogen	(trace)

Therefore hydrogen passes completely out through the walls of the tube, and air is absorbed in spite even of an excess of pressure amounting in some cases to several centimetres of mercury.

Diffusion Apparatus.—Deville then proceeds to describe his celebrated diffusion apparatus — which is shown diagrammatically, Fig. 9—which he used in so many experiments. An internal tube of unglazed biscuit—or earthenware—passes centrally through a larger and shorter tube of glazed porcelain, the ends of the latter being closed by rubber stoppers or corks. The gas to be studied is passed through the annular space between the tubes. The apparatus can be heated along its middle portion by a coke furnace to a temperature of from 1100° to 1300° C.[2]

Hydrogen and CO_2 Experiments.—Employing this apparatus cold, Deville makes the following experiment: A fairly rapid current of CO_2

[1] *Leçons sur la Dissociation professées devant la Société Chimique de Paris.* 1864.

[2] No data are given by which this temperature estimate can be even approximately verified, but no blast appears to have been used, hence 1500° C. would be a probable maximum.

is led through the outer space, while a current of hydrogen is led through the inner tube in the opposite direction. It is found that hydrogen diffuses outwards so rapidly that it can be lighted at the exit of the CO_2 tube, while very little or none escapes from the end of the inner porous tube. 'Thus by virtue of "endosmose" the two gases have changed places, traversing in opposite directions, the porous wall separating them. These phenomena, forming a striking and instructive lecture experiment, are in perfect agreement with the observations already made by Graham and by Jamin.'[1]

After this preliminary investigation of the action of his apparatus when cold, Deville proceeds to study by its means the action of heat on steam, using CO_2 as the inert gas. Steam being led in by the outer tube, the products collected from the inner one, after absorption of the CO_2, were found to be strongly explosive. In several experiments the average amount of explosive gas collected was 1 c.c. per gram of steam passed in.

(2) *Dissociation of Steam.*—A porcelain tube, five or six cm. diameter, was filled with fragments of very clean porcelain previously heated to redness. A rapid current of CO_2 was led through a flask of water maintained at 90° or 95° C., and thence through the porcelain tube, heated to full redness in 'a furnace using a blast of air.' It is easily seen that a small quantity of steam is broken up into its elements. The gas passing out of the tube is collected over strong potash solution. After two hours 25-30 c.c. of an explosive mixture was obtained, which gave, on analysis:

O_2	46
H_2	35
CO	12
N_2	6

the speed of the gas current averaging seven or eight litres of CO_2 per hour. The quantities of gas obtained are only about a quarter of those got in a similar time by the first method. A blank test on the carbonic acid gas gave 1·6 c.c. of residue, instead of 25-30 c.c.

Dissociation of CO_2.—In another paper, describing the same kind of experiment on CO_2 alone, the author adds some further details. He says: 'I have proved the dissociation of water at a moderately high temperature by separating it into its elements by the action of a solvent (some experiments not discussed here) or by the action of a mechanical pheromenon. I have succeeded *still more easily* with CO_2, because of the resistance to combination shown by oxygen and carbonic-oxide when they are disseminated through the mass of an inert gas. Fortunately for the rigour of my demonstration the gas may be CO_2 itself. I take the porcelain tube filled with porcelain fragments, as previously described. This apparatus is carried to a temperature which I estimate at 1300° C.'

An analysis of the residual gas gave:

$$\left.\begin{array}{l} O_2=30 \\ CO=62 \\ N_2=\ 8 \end{array}\right\}\text{average of several samples.}$$

[1] Analyses of the gases passing into the collecting vessel did not always give the same result, thus casting some suspicion on the experiment, particularly on the gas-tightness of the porcelain tube. Deville would not admit that his porcelain was porous, but says that his joints were not all secure against small leaks of hydrogen.

If the same quantity of the original CO_2 is made to pass the potash solution, and the residue is collected, this measures at the end of the same lapse of time 1·4 c.c., consisting of

$$O_2=14,$$
$$N_2=86,$$

which accounts for the small quantity of nitrogen in the products of dissociation of the CO.

The 'Cold-Hot' Tube.—In this arrangement the recombination of the dissociated gases is prevented by rapid cooling, instead of diffusion and dilution, as in the previous experiments. A thin brass tube, silvered externally, takes the place of the porous inner tube of the first apparatus. Through this is maintained a rapid and steady current of cold water.

Experiments on CO.—A current of pure CO, made by the action of sulphuric acid on oxalic acid, is passed through the outer tube of the apparatus. The CO_2 in the CO is absorbed by passing through several wash-flasks of potash, then over a tube of iron, filled with red-hot iron wire, and finally more potash vessels. The exit-tube from the furnace passes to a baryta solution. As soon as the tube becomes red-hot, CO_2 is shown in the issuing products. Carbon deposits on the under side of the silver tube as soot.

Modified 'Cold-Hot' Tube.—The same arrangement as just described was modified by boring a hole about 0·2 mm. in diameter through the metal tube, and attaching to the outlet for the water a long glass tube bent vertically downwards. This acts like the old form of Bunsen pump, causing some gas to be drawn inwards at the hole, and to pass on with the current of water. The lower end of the water-delivery tube is bent so as to allow the gas issuing to be collected in an eudiometer. With this apparatus Deville considers he showed CO_2 to be 'strongly dissociated at 1200° C.'

Sparking Experiments.—This is confirmed by a sparking experiment.

If CO_2 confined over mercury in an eudiometer be sparked vigorously in presence of phosphorus, all the oxygen is absorbed as fast as produced, and the dissociation is complete.

Consideration of the papers, of which the above is an abstract, and also others not dealt with, has led me to believe that Deville may be more right as regards the magnitude of the dissociation produced in steam and CO_2 by heat than recent writers on the subject would lead us to suppose. Each experiment considered alone would not be unimpeachable, but although there appear to be many pitfalls and possibilities for secondary effects to interfere with the reactions studied, yet the evidence seems so strong that it is hardly possible to discredit it. If this be the case, further work on the lines indicated by Grove and Deville, accompanied by proper temperature measurements, would seem very desirable.

For a repetition of the first experiment an external 'guard-tube,' coming outside the glazed porcelain tube and conveying a stream of the gas to be studied, would be an obvious improvement. This would enable the effect of small leaks in the porcelain tube to be minimised. The glaze of the best Berlin tubes softens and is distinctly 'tacky' at 1150° C., while after long exposure to 1200° C. the glaze sinks in and perishes. Silica tubes begin to sag, when unsupported in the hot parts,

at about 1240° C., and could not be used for hydrogen at any temperature above a dull-red heat, so that until gas-tight tubes of some more refractory material are available, there does not seem much probability of being able to repeat the experiments at higher ranges.

In view of the fact that Crafts states that the dissociation of CO_2 is still inappreciable at 1500° C.,[1] a statement confirmed by the more recent work of Nernst and Wartenburg, a careful repetition of Deville's experiments is very necessary.

If some such amount as 1/400th of the whole gas is proved to be dissociated at temperatures of the order of 1200° C. (and it is to be remembered that the amount found by all these methods is necessarily a minimum limit), then at gas-engine temperatures it is probable that the total dissociation is much larger, and hence the rise in the apparent specific heat of the gas might be quite appreciable.

The dissociation of carbon monoxide seems proved beyond doubt at Deville's temperatures. He says it is detectable at the melting-point of glass, and is *marked* at the melting-point of silver, as proved by the inverse reaction of passing CO_2 over carbon at that temperature. This is undoubtedly of great importance, if true; perhaps some of the chemists on the Committee can give us further information.

The Lake Villages in the Neighbourhood of Glastonbury.—Report of the Committee, consisting of Dr. R. MUNRO *(Chairman)*, Professor W. BOYD DAWKINS *(Secretary)*, Professor W. RIDGEWAY, *and* Messrs. ARTHUR J. EVANS, C. H. READ, H. BALFOUR, *and* A. BULLEID, *appointed to investigate the Lake Villages in the neighbourhood of Glastonbury in connection with a Committee of the Somerset Archæological and Natural History Society.*

THE Committee have to report that owing to the amount of work thrown on the hands of Messrs. Bulleid and St. George Gray in compiling and arranging the details of the monograph on Glastonbury Lake Village, it was found inexpedient to resume excavations this summer on the new site at Meare. The expenses incurred in the preliminary excavations carried on at Meare last summer have already been paid by Mr. Bulleid, and, consequently, no part of the 5*l.* grant made by the Association has been expended. The Committee have therefore to recommend that this grant be renewed, together with at least 30*l.* in addition. With a sum of 35*l.* assured, and the number of private contributions already announced, the Committee hope to make considerable progress in excavating the Meare Lake Village during the summer of 1910. Judging from the discoveries already made and recorded (Tenth Report, Dublin Volume, p. 414), this new lacustrine site promises to be richer in archæological remains than even Glastonbury.

[1] I have not been able to find the original paper dealing with this. It is probably in one of his papers on the gas-thermometer. The fact is quoted from Mallard and Le Chatelier's papers in the *Annales des Mines*: 'Recherches sur la combustion des Mélanges gazeux explosifs,' p. 275.

Excavations on Roman Sites in Britain.—Report of the Committee, consisting of Professor J. L. Myres (*Chairman*), Professor R. C. Bosanquet (*Secretary*), Sir Edward Brabrook, Dr. T. Ashby, Mr. D. G. Hogarth, *and* Professors W. Ridgeway *and* W. Boyd Dawkins, *appointed to co-operate with Local Committees in Excavations on Roman Sites in Britain.*

The Committee report that in the course of recent excavations, conducted jointly by the Chester Archæological Society and the Liverpool Committee for Excavation and Research in Wales and the Marches, on the site of a newly discovered section of the Roman Wall at Chester, a palæolithic implement was discovered in made earth near the base of the wall. Such a discovery is of the highest interest, in view of the fact that palæolithic implements are not usually found in Great Britain so far to the north-west. It has appeared, therefore, to be of importance to ascertain more exactly the character of the deposit in which this implement was found, and the Committee's grant of 5*l.* has been placed at the disposal of Dr. Robert Newstead, of the Chester Museum, for this purpose. Dr. Newstead's report has not yet been received.

The Committee ask to be reappointed with a further grant.

The Age of Stone Circles.—Report of the Committee, consisting of Dr. C. H. Read (*Chairman*), Mr. H. Balfour (*Secretary*), Lord Avebury, Professor W. Ridgeway, Dr. J. G. Garson, Dr. A. J. Evans, Dr. R. Munro, Professor Boyd Dawkins, *and* Mr. A. L. Lewis, *appointed to conduct Explorations with the object of ascertaining the Age of Stone Circles.* (*Drawn up by the Secretary.*)

In planning the arrangements for further excavations at Avebury Stone Circle, in continuance of the work done last year, the Committee were of opinion that the most satisfactory results were likely to be obtained from renewed examination of the silting in the fosse, particularly the lowest layers occupying the original bottom of the huge trench. It was also considered desirable, as a minor operation, to explore the ground at the base of one or more of the prostrate stones of the circle, with a view to examining the original sockets in which the stones stood when erect. Instructions were accordingly given to Mr. H. Gray, whose services were again secured, to concentrate attention upon these two main objects. The details of the excavations, and the results obtained, are given in the appended report by Mr. Gray, and the Committee have every reason to feel satisfied with the manner in which the work has been carried out, and the care with which the exact position of all 'finds' has been determined and recorded.

To expose even a small area of the original bottom of the fosse is of necessity a work involving great labour, owing to the enormous amount of silting which must be moved; and in view of the smallness of the available grant, it was necessary to invite subscriptions from

other sources. The response made to the appeal for funds has been gratifying, substantial assistance having been forthcoming from societies and from private individuals. A list of donations appears in the accounts for the year, and the Committee take this opportunity for thanking those who have contributed so generously; without their assistance, work on any substantial scale would have been impossible. The Rev. E. H. Goddard very kindly undertook to collect subscriptions from members of the Wilts Archæological Society. The thanks of the Committee are also due to Lord Avebury and to Captain Jenner for permission to conduct excavations on their property; also to the Rev. T. G. Ward, Vicar of Avebury, for assistance in securing labourers. The Committee wish also to acknowledge gratefully the courtesy with which the Somersetshire Archæological Society made it possible for Mr. Gray to have leave of absence from Taunton during the period of the excavations.

The main result achieved from the deep cuttings in the fosse is a confirmation of the opinion arrived at last year as to the probable date of the monument. Additional positive evidence has been obtained from the objects discovered in the lowest layers of silting, and on the original bottom of the ditch. These in all cases are objects such as are characteristic of the Neolithic period, and although it would be hazardous to state definitely that they *must* be of Neolithic date and cannot belong to the Bronze Age, the negative evidence, afforded by a total absence of copper or bronze, and of objects which are *certainly* of Bronze Age, affords powerful confirmation of the probability of the earlier date being the right one. A transverse section of the fosse close to the modern road was expected to reveal the sloping sides of the causeway presumed to exist, connecting Kennet Avenue with the interior of the monument, since at first sight it seemed likely that the road would have followed the line of the causeway. No trace of the latter, however, appeared in this section, and as it was of considerable interest to ascertain whether or not such a causeway had existed, exploring trenches were cut on the opposite side of the road, and the causeway was discovered to the east of the present roadway. This locating of the original line of approach to the interior of the huge circle is a most interesting result of this year's excavations.

Sectional and other plans of all the parts excavated have been prepared with very great care, and a large number of excellent photographs are now available.

The grant from the Association having been expended together with most of the money raised by subscriptions, it becomes necessary to apply for a fresh grant to carry on the work. The Committee ask to be reappointed and apply for a grant of 75*l*., and also for leave to invite subscriptions in order to make up a sum sufficient for carrying out effective exploration. The huge scale of the earthwork renders its investigation comparatively costly and laborious, as the mass of silting in the fosse is very great. It is very desirable to continue the work next spring, in order that making good the already disturbed ground and conducting fresh exploration may proceed together. The advantage, moreover, of being able to secure men who have already worked under Mr. Gray's supervision is obvious, and some of those employed in this year's excavations would no doubt be available next year; continuity in their employment would undoubtedly save much

trouble in training them to the work. The thorough investigation of this splendid monument is of the greatest importance, and it is to be hoped that adequate funds may be available.

The Avebury Excavations, 1909. *By* H. St. George Gray.

I. *Introductory Remarks.*

In the report of the excavations, 1908 (Brit. Assoc. Reports, 1908, pp. 401-413), an epitome was given of the existing archæological literature on Avebury, having reference to its stone circles, surrounding earthworks, and ancient remains in the immediate neighbourhood; and a summary representation of the opinions and observations of several authorities on Avebury, including Aubrey, Stukeley, Hoare, Crocker, W. C. Lukis, Fergusson, and the Revs. A. C. Smith and Bryan King, was also placed on brief record. In another section a condensed account was given dealing with previous and less extensive excavations which had been conducted in various parts of 'the Temple' between 1865 and 1894; none of these, however, produced any definite evidence of date, for the reason, mainly, that scientific method in archæological field-work had not then attained to the standard aimed at in the present century.

Having dealt with Avebury under these headings in the previous report, the present account will be almost confined to the excavations conducted from Monday, April 26, to Monday, May 17, the filling-in, completed this year, continuing till May 20.

A maximum number of sixteen men was employed this season, eleven being engaged in 1908.[1] The weather was highly favourable during the three weeks, only four hours being lost owing to rain. Last year we were much hindered by falls of silting from the almost vertical sides cut as the digging penetrated into the lower levels of the great fosse. But, having grown wiser, we left a considerable batter to the faces of the silting this season, at the expense, however, of uncovering a relatively shorter length of bottom of the fosse.

A number of sectional diagrams were made as the work proceeded, in which the various soils were indicated, and the exact position of every object of importance found during the exploration was projected into these sections, notes being made relating to each numbered 'find.' Eleven sectional drawings and plans were made, and a scale map of the whole area excavated in 1908 and 1909. An average section of the southern fosse having been given in the Report of 1908, it will be unnecessary to publish another on the present occasion, the previous one being fairly representative of the other sections made for the sake of careful record and precision.

Twenty-two satisfactory photographs (half-plate) were taken during the season and sixteen last year, some showing the progress in the excavations from time to time as new features presented themselves, others being interesting views of various parts of 'the Temple' taken under favourable conditions of light.

The excavations were visited by some of the members of the British Association Stone Circles Committee, by Fellows of the Society of Anti-

[1] The foreman on this occasion (J. Lush) had previously done deep digging in the chalk at the Maumbury Rings excavations at Dorchester last year.

quaries, and by members of the Wilts Archæological Society, and Marlborough College Natural History Society.

Most of the excavations have now been filled in, but Cutting II through the fosse has been left open for the inspection of visitors during the summer.

II. *Geological Note.*

Avebury is on the Middle Chalk, but Mr. A. J. Jukes-Browne, F.G.S., informs us that the area has not yet been accurately mapped, and it is uncertain whether the site stands on the *Terebratulina gracilis* zone or that of *Rhynchonella Cuvieri*. Of the fossils from the Avebury fosse, 1909, all are *Inoceramus mytiloides* except two, which are *Rhyn. Cuvieri*. Mr. Browne also reports that ' the evident abundance of *Inoc. mytiloides* is greatly in favour of the zone of *Rhyn. Cuvieri;* they are seldom abundant in that of *Terebratulina*, which always consists of fairly soft white chalk, while that of *Rhyn. Cuvieri* is harder, more nodular, and often yellowish.'

Iron pyrites were commonly found in the fosse cuttings.

III. *Excavations into the Fosse.*

(*a*) *Cutting I.*—Rather more than three-quarters of the silting from this cutting was re-excavated last year. It was 24 feet long, all the upper deposits down to the top of the Roman stratum being removed in 1908, and a length of 17 feet cleared at the bottom (B.A. Report, 1908, pp. 408-410. It remained, therefore, to uncover 7 feet on the E. margin this year. Roman pottery was found at depths of 5·7 and 6 feet respectively, and a human clavicle, depth 8·5 feet). The mixed silting was reached at a depth along the E. margin of 9·1 feet (the depth on the W. margin being 8·7 feet). After having penetrated the chalk rubble to a depth of 12 feet from the surface a large fall of several tons of material from the E. face had to be contended with, and, although the labour entailed thereby was considerable, the final results were satisfactory. Eventually the bottom along this margin was reached at a depth of 17·8 feet from the surface of the silting, and we were rewarded by finding, in all cases on the floor, four antler picks (Nos. 131, 133, 135 and 136), which are described below. Cutting I produced in all (1908-09) parts of ten picks of red-deer antler and a shovel of shoulder-blade bone—implements which had been used in the original excavation of this huge fosse.

But the most interesting discovery on the floor was the chipped flint knife, a piece of flint full of sponge-spicules which appears to have been slightly scorched but never burnt red-hot, and a piece of charcoal. The knife, described below, is not only of characteristic Neolithic type, but most probably of Neolithic date. It is of a kind frequently found on the site of an ancient factory of flint implements on Windmill Hill, about a mile to the N.W. of Avebury.

The following objects were found in Cutting I in 1909:—

109. Fragment of thin grey Roman pottery. Depth, 6 feet.

116. Handle of a vessel of grey pottery, painted brick-red; Roman. Depth, 5·7 feet.

113. Greater part of a human *clavicle*. Depth, 8·5 feet at the bottom of the fine mixed silting.

111. Well struck narrow flint flake. Depth, 7 feet.

132. Chipped flint knife of ovoid form, with a deep white patination; length, 89 millimetres; maximum width, 44 millimetres; the point appears to have been broken off. One face is quite roughly chipped; the other presents a smooth surface, although there are no indications of polishing; the cutting-edge on this face is finely worked. It was found resting on the bottom of the fosse at a depth of 17·8 feet below the surface of the silting, S.E. part of the cutting. Close to it, also on the floor, were found the antler pick (No. 135), a piece of scorched flint, and a piece of charcoal.

131. Small shed antler with brow- and bez-tines broken. The more perfect parts show no signs of wear, and it is uncertain if this specimen was ever used as a pick; the head shows no signs of hammering. Depth, 17·8 feet on the bottom.

133. Fine antler of slain deer, which has evidently been used as a pick; the bez-tine remains only as a short stump, but both the brow- and the trez-tine show considerable evidence of use, the former having a smooth rounded point, the finely developed trez-tine not being worn down, but the tip is extremely smooth. The grip of the handle is also smooth, as in No. 90 found last year. The tool was also used for hammering on the side opposite to the brow-tine. Depth, 17·8 feet on the bottom.

135. Pick, the shed antler being now missing beyond and including the trez-tine. The brow-tine is complete, showing signs of wear at the rounded point; the bez-tine has been intentionally removed; the back of the burr bears indications of hammering. Found on the bottom of the fosse.

136. Pick (present length, 20½ inches) bearing considerable indications of prolonged use, the brow-tine being worn down to a length of 3 inches. The bez- and trez-tines remain only as stumps. The antler was shed. It is interesting from the fact that the base for a length of 4 inches from the burr is battered by hammering to a very considerable extent, and undoubtedly this tool had proved to be a most serviceable one.

(*b*) *Cutting II.*—This cutting was pegged out last year also to a length of 24 feet, the W. margin being 69 feet to the E. of the W. margin of Cutting I. Being nearer the road on higher ground, it was obvious there would be a greater amount of surface silting to remove than in Cutting I. Last year a length of 9·5 feet was dug to a depth of 5·5 feet, and in the re-excavated material were found a number of shards of Norman and mediæval pottery (B.A. Report, 1908, p. 410). It was at this point that we continued operations this year. The surface silting was found to extend to an average depth of 5·8 feet in the middle. Nothing worthy of particular record was found in it: but a number of shards of mediæval date and even later, together with an Irish halfpenny of George III and a seventeenth-century tobacco-pipe of clay, bearing the name of 'Thomas Hunt' on the heel, were collected from depths varying from 1 to 3 feet. Another tray of pottery of similar character was preserved from depths of from 2 to 4·5 feet, and other mediæval fragments were found along the E. margin of the cutting at depths between 4·5 and 5·8 feet. The upper deposits had probably been disturbed, and further inquiries led me to believe that the surface of this part of the fosse had been cultivated up to the third quarter of last century.

The next deposit—mixed silting, consisting of mould with a larger proportion of small pieces of chalk—extended to an average depth of 10·3 feet in the middle. The lower 2 feet of this silting was found to be of a finer kind with a smaller admixture of chalk.

Eight lots of Roman or Romano-British pottery were found in the

mixed silting at depths varying from 5 feet to 8 feet, all of which are described below. One piece (No. 118) was picked up at a depth of 8·5 feet, but it may have tumbled down during the digging. Several pieces of pottery of Bronze Age type were also found in the mixed silting at depths between 8·5 and 9·5 feet and above the pure chalk rubble. This pottery was of the soft smooth hand-made cinerary-urn type containing few grains of quartz; one piece (No. 134) has a typical cordon or encircling ridge. This deposit also produced human remains in two places (Nos. 117 and 122) to a maximum depth of 9 feet. Flint flakes were also found, and four objects of flint, numbered 106, 110, 125, and 138 below, including a good specimen of an oval scraper.

Between the mixed silting and the chalk rubble in the middle part of the silting, tapering in both directions, a seam of crystallised chalk, almost impenetrable to the pick-axe (indeed, it broke two points), was reached; it occurred at the same level in all the cuttings made. Carbonate of lime had consolidated the chalk and rendered it as solid as the hardest concrete to a thickness of a foot in places. The workmen considered it to be the bed of an ancient watercourse! In any case, there must have been a considerable soakage of water to deposit carbonate of lime in such quantity.

Owing to the curvature of the stratum in the silting, the chalk rubble on the sides of the fosse extended almost to the top; in the middle it was reached at a depth averaging 10 feet. From here to the bottom, as elsewhere, silted chalk rubble only had to be removed, with thin seams of dark mould caused by the occasional falls of turf. A piece of early British pottery was dug up at a depth of 8·7 feet near the southern margin of the fosse. No other pottery was discovered, but four pieces of worked flint (numbered) were found at depths between 6·5 feet and 9·5 feet (none in the middle depths of the fosse).

The greater parts of two antler picks were found in deep positions, as described below. Six of these picks were recovered during the season. Since the Avebury Report, 1908, was written explorations at Maumbury Rings, Dorchester (which I had the charge of), revealed a Neolithic shaft, 30 feet deep, in the solid chalk below the floor of the Roman arena, in which no less than nine antler picks were found, some being in good preservation, two having the smoothed grips like some of the examples from Avebury and the Grime's Graves.[1] The Dorset County Museum contains parts of antler picks also from Jordan Hill, Fordington, Hambledon Hill, &c.

Close to the bottom of Cutting I last year we found a fragmentary *scapula* in a shattered condition, its position, &c. (B.A. Report, 1908, p. 410), suggesting its use as a shovel of the character of those found in the Neolithic flint-workings at Cissbury, specimens from which may be seen in the British Museum and the Pitt-Rivers Museum at Oxford. A number of worked *scapulæ*, one being finely ornamented, were found in the Meare Lake Village. In the 1909 excavations at Avebury three well-defined specimens of these shovels were found in Cutting II fosse, two (Nos. 129 and 137) shoulder-blades of ox (*Bos longifrons*) being found on the floor of the fosse at depths of 18·5 and 18·8 feet respectively; the other (No. 145) was a *scapula* probably of pig (*Sus scrofa*), found at a depth of 14·3 feet in the chalk rubble, having perhaps slipped down from

[1] *Proc. Dorset Field Club*, xxix. 270.

the vallum before it became turf-clad. The two shovels of *scapulæ* of ox measure 13¾ inches and 12½ inches in length. In two cases (Nos. 129 and 145) the large anterior spine has been cut away, or partly removed, and from this fact and the worn appearance of the three specimens, together with the great scarcity of other animal remains except the antler picks at such a great depth, we think it more than probable that they were used as shovels in the original excavation and clearing of the fosse.

The bottom of the fosse, Cutting II, was just as smooth as in Cutting I, but it narrowed slightly. In Cutting I the width at the bottom varied from 16 to 17·3 feet. In the W. half of Cutting II it varied from 11·8 to 17 feet; in the E. half it averaged 14·3 feet. The walls of the fosse in the lower parts (Cutting II) became steeper and were very uneven, there being considerable projections of hard chalk, left apparently for no particular purpose. We experienced no fall from the E. face of the silting, it being sloped as the excavation proceeded to the extent of 4½ feet out of the vertical. The bottom was found to rise towards the east slightly, and along the E. margin a ridge (height about 0·9 foot) of solid chalk crossed the fosse as shown in one of the sectional diagrams; in the middle of the ridge was a slight hollow. We could not, of course, ascertain whether this sudden slight rise continued in an easterly direction.

The depth of Cutting II from the surface of the silting on the west was 18·8 feet; on the east 20·5 feet; the difference being accounted for from the fact that the surface rises considerably towards the road.

The following numbered 'finds' were recorded in Cutting II, 1909:—

126. Piece of base and rim of an early mediæval pot, with fingermark indentations round the edge of the bottom. Depth, 3·2 feet.

101. Piece of hard grey Roman pottery, painted brick-red inside and out; thickness, 7·5 millimetres. Depth, 5 feet.

102. Fragment of thin Roman pottery, pale grey on the inner face, brick-red on the outer. Depth, 6·2 feet.

104. Part of base of a coarse brown pot; Romano-British or Late-Celtic. Depth, 8 feet.

108. Small piece of red pottery of a smooth, soft paste; Roman. Depth, 4·5 feet, near the wall of the fosse and in the chalk rubble just below the mixed silting.

114. Several fragments of a lathe-turned vessel of brown ware of a very sandy texture; Romano-British. Depth, 5·8 feet.

115. Three fragments of Roman vessels of different qualities. One piece is of sandy texture like No. 114; another greyish-brown ware; the third a fragment of thin grey pottery painted brick-red on both sides. Depth, 6·8 feet.

118. Piece of thin grey ware and a fragment of dark brown ware; Roman. Depth, 8·5 feet.

130. Two pieces of Romano-British dark brown ware of sandy texture like No. 114. Depth, 7 feet.

107. Small piece of soft British pottery, black on one side, red on the other. Depth, 8·7 feet, near the south side of the fosse, in the chalk rubble.

119. Small fragment of pottery of British type containing small grains of quartz. Depth, 9·3 feet in the mixed silting, just below the Roman deposits.

123. Four pieces of soft British pottery (the No. 2 type of Pitt-Rivers), reddish-brown in colour. One piece is ornamented with a row of three

finger-nail impressions. Another is the straight rim of a hand-made vessel; the top of the rim is bevelled inwards; average thickness, 12 millimetres. Depth, 8·5 feet.

134. Piece of thick soft British pottery of cinerary-urn type, black on the inside, brick-red on the outer surface. This specimen is crossed on the outer face by one of the typical cordons or ridges. Depth, 9·5 feet at the bottom of the mixed silting.

117. Part of a human *femur* and three-quarters of a *humerus* (least circumference, 59 millimetres). Depth, 9 feet in the mixed silting.

122. Part of a human *femur* and *radius*. Depth, 7·9 feet in the mixed silting.

105. Small flint scraper of long, narrow form, which from its position in the chalk rubble near the edge of the fosse might perhaps be of Neolithic date. Depth, 7·8 feet.

106. Pointed implement of flint with thick white patination, having slight traces of secondary chipping; length, 66 millimetres. Depth, 7 feet in the Bronze Age stratum of the mixed silting.

110. Flint knife worked along one edge; length, 30 millimetres. Depth, 5·3 feet in the mixed silting.

112. Worked flint flake, with prominent bulb of percussion. Depth, 6·5 feet near the margin of the fosse.

120. Flaked flint knife of ovoid shape; length, 40·5 millimetres. Depth, 9·5 feet in the chalk rubble. Bronze Age or Neolithic.

125. Flint scraper of bluish-brown flint, showing part of the crust, with bevelled edge. Depth, 6·8 feet in Bronze Age stratum.

138. Oval flint scraper, 46 by 38 millimetres, with deep bevelled edge. Depth, 9·5 feet in the Bronze Age stratum.

146. Flint core (? sling-stone). Depth, 9·5 feet.

124. Pick of antler, worn out from prolonged use, very little now remaining of the brow-tine. The bez- and trez-tines exist as stumps. The pick shows signs of having been used for hammering in the usual position. The smooth grip remains in a damaged condition. The antler is a shed one with a heavy straight beam. Depth, 18·8 feet, on the bottom of the fosse.

128. The greater part of the beam of an antler pick, the base deficient, the trez-tine remaining as a stump. Signs of hammering in the usual position. Depth, 16·5 feet in the chalk rubble, near the bottom.

129, 137, and 145. Bone shovels, previously described fully.

(*c*) *Flint Flakes.*—These were numerous from Cuttings I, II, and III, and many of them were fine examples, with well-defined bulbs of percussion. The following were collected in 1908 and 1909:—

Cutting I	73
Cutting II	119
Cutting III	99
	291

The depths of all were recorded. In Cutting I, 8 were found in the surface silting, 29 in the mixed silting, and 36 in the chalk rubble. Of these 1 was found at 11 feet deep, 1 at 14 feet, and 2 at 15 feet.

In Cutting II, 18 were found down to 5 feet, 97 from 5 feet to 10 feet, 2 at 11 feet, 1 at 12·5 feet, and 1 at 17·5 feet.

In Cutting III, 21 were found down to 6 feet, 65 from 6 feet to 12 feet, and 13 from 12 feet to 13·5 feet.

(*d*) *Cutting III*.—The E. margin of Cutting III was only 6 feet W. of the middle of the western hedge bounding the modern road into Avebury from the south. A length of 14 feet of fosse was marked off for examination. It was close to the gate of the high road, and was dug to ascertain if the fosse rounded off to form a solid entrance-causeway.

Both Aubrey and Stukeley apparently show the position of the Kennet Avenue entrance into Avebury as being exactly on the site of the present road, and this fact rather led one to suppose that the fosse of the W. side of the solid entrance-causeway must have terminated in about the position of the present western hedge. But our excavation into the fosse of Cutting III proved that their plans are incorrect and misleading.

In 1909 (B.A. Report, p. 410) we made several trial holes to ascertain the direction towards the east taken by the upper margins of the walls of the fosse exposed in Cutting II. Holes were made along both margins, and in all those nearest to Cutting II the solid chalk upper border of the fosse-wall was revealed; but instead of the fosse narrowing it widened as it approached the hedge and road.

This year before re-excavating a part of Cutting III we dug a trench about 32 feet long and 5 feet wide, connecting the northern face of Cutting II with the northern face of Cutting III, and clearly exposed the upper walls of the fosse. On the top of the solid chalk ' wall ' in the N.N.E. corner of Cutting II a slight platform was observed. It was found on excavation to continue a little towards the north, but judging (1) from the apparent hollows in the turf-clad inner bank for some little distance round, and (2) the fact that modern shards were found down to the solid chalk, it appeared evident that a recent excavation had been made here, perhaps for chalk, as in the much larger mutilation in the vallum opposite on the south.

Having re-excavated Cutting III to a considerable depth we felt bound to complete the northern portion of it to the bottom, which the fine weather permitted us to do, but, as we shall see presently, we proved the existence and position of the ancient entrance-way on the E. side of the modern road.

It soon became clear in digging Cutting III that the fosse approaching the causeway from the west not only maintained its great depth, but expanded considerably towards the point where it rounded off to form the causeway under what is now the high road into Avebury. (This will be clearly shown in the plan to be reproduced hereafter.)

The top margin of the fosse in Cutting III proved to be 52 feet wide, and the whole of the filling to a depth of 5 feet was removed. This produced no object of importance and consisted entirely of silt from the hedge and road and a loamy tenacious material said by the local people to have been brought to this spot from the site of the ' New Bridge ' across the Kennet stream on the Devizes road, a quarter of a mile S.W. of our diggings, when it was built. It entailed much manual work to remove this ' dumped ' material, but afterwards we came upon the same ancient deposits as occurred in Cuttings I and II, making ' finds ' of pottery and a well-worn flint scraper (No. 140), described below.

At length we reached the bottom at a depth of 23 feet from the surface, but nothing was found in the lowest depths but a *scapula* of sheep at 18 feet; and no remains actually on the smooth floor of the fosse, which was exposed for a width of 8 feet and a length averaging 3·8 feet. In no part of the excavations could one realise better the immensity of the

great fosse and the labour its construction must have entailed when metals were unknown in Britain. This inner slope of Cutting III was the finest example of cut chalk exposed in any part of the excavations; and the uniformity of the slope and the absence of projections seemed to indicate that the fosse was originally excavated with greater care near the entrance-causeway than elsewhere. The average inclination of the fosse wall was at an angle of 63½°, and covered a length of 26·5 feet on the slope; but the steepness of the profile in the lowest 6 feet was remarkable, being at an angle of 81°, the chalk resting in immense solid blocks in its natural condition. No ancient tool-marks were observable on the walls of the fosse, near the bottom or elsewhere.

The following specimens were collected from Cutting III:—

139. Fragment of the base of a mediæval pot; depth, 6 feet. Mediæval pottery was less plentiful in Cutting III than elsewhere; we have, however, a tray of shards from depths between 4 and 5·5 feet.

144. Two small pieces of grey Roman pottery. Depth, 9·5 feet.

143. Fragment of coarse brown pottery with smooth faces; apparently of Late-Celtic type. Depth, 11 feet.

142. Fragment of light brown pottery containing very few grains; probably Bronze Age. Depth, 12·3 feet.

140. Finely worked discoidal flint scraper bearing indications of considerable use, and having a deep bevelled edge. Depth, 9·5 feet in the mixed silting.

141. Roughly chipped implement. Depth, 9·5 feet in the mixed silting.

147. Flint core. Depth, 12·5 feet in the mixed silting.

IV. *Excavations in the Position of the Ancient Southern Entrance.*

Cutting III having given us no evidence of the position or existence of a southern entrance into Avebury, we found it necessary to pay attention to the area to the east, on the other side of the high road, both near the two large standing-stones of the outer circle on the property of Lord Avebury and in the position of the plantation of beech trees owned by Capt. Jenner, the two properties being divided here by a barbed-wire fence. The trees were noticed to be planted on a slight ridge so near the road that it was thought possible that it might be the result of a collection of rubbish from the highway and elsewhere, and especially as the position is covered on the south by the end of the outer vallum which appears to obstruct any direct approach to the most northern remaining stone of the Kennet Avenue. But it was, on closer examination, observed that the slight ridge also extended towards the north into the meadow in the direction of the space (24 feet) which exists between the two remaining standing-stones of the outer circle.

(*a*) *Cutting IV.*—Forthwith we made a cutting (No. IV), length 47 feet, width 5 feet, approximately at right angles to the ridge and 23 feet from the most westerly of the standing-stones. Here we reached the solid chalk in the middle of the cutting at a depth of 2 feet from the turf, and there appeared to be no sign of a continuation of the fosse in this position. The same depth was maintained to the most easterly part of the cutting, but there were occasional dips in the chalk which appeared to have no special significance. At 28 feet from the eastern end there was a step in the solid chalk down to a depth of 3 feet from the surface;

at 33·5 feet another step to a depth of 4 feet from the surface; then a level floor for about 5·5 feet, followed by a gradual slope downwards to a depth of 4·5 feet. Having almost reached the hedge we could go no further. But we had struck the causeway and what appeared to be steps down to the brink of the ancient fosse at its termination on the west of the entrance.

A large number of shards, glazed and unglazed, were found between the turf and a depth of 18 inches in the middle parts of the cutting; all of which appeared to be mediæval and later ware. In the deeper part on the west a few pieces of brown pottery, which we regarded as mediæval, were found in or on a distinctly blackish-brown seam of mould, the result probably of disturbance at such a time as the modern bank and hedge were made.

(*b*) *Cutting V.*—The next cutting made was close to the fence on Captain Jenner's property. The western half was cut 5 feet wide, the eastern 3 feet. It was begun close to the road-fencing and continued in an easterly direction for a distance of 54 feet. At 29 feet from the eastern end the solid chalk was reached at a depth of 1·4 foot from the surface—the level of the ancient causeway. From this point eastwards the surface of the ground sloped towards the eastern fosse; likewise the solid chalk sloped downwards gradually, not evenly, but in rough shallow steps. At 50 feet from the western end of the cutting the solid chalk shot down suddenly at an angle of 46°, at which point the brink of the eastern fosse was undoubtedly reached. The western end of the cutting is more difficult to describe, because we met with a modern earthenware drain-pipe, for draining the surface-water from the modern road into the eastern fosse, the placing of which had destroyed the contour of the solid chalk as left by the constructors of the causeway. (The sectional diagram of this cutting shows the line of the chalk as it exists at present.)

(*c*) *Cutting VI.*—Another cutting (length 56 feet, width 2·5 feet) was made close to and parallel with the barbed-wire fence, and on Lord Avebury's side. This revealed the solid chalk running level for a length of 26 feet, the nearest part of the surface of the turf being at a depth of 1·6 foot. At 19·5 feet from the west end of the cutting the solid chalk dropped in two steps towards the western fosse, in the same manner as described in Cutting IV. At the east end of the cutting the chalk sloped off very gradually.

(*d*) *Cutting VII.*—This narrow cutting was dug amongst the beech trees on the Jenner property. The length examined was 50 feet, but a part in the middle had to be left untouched on account of the large roots of the trees. This cutting gave clear evidence that the causeway was 24 feet wide at the top in this part, and at a minimum depth of 1·8 foot from the surface. From the margins of this ancient road of solid chalk, rough steps downwards were traced in both directions. In the eastern half the brink of the fosse was reached at a distance of 14 feet from the eastern margin of the top of the causeway, from which point the solid chalk had been cut abruptly downwards at an angle of 51°, into the depths of the fosse below.

No relics of datable importance were found in any of these cuttings.

V. *Excavation round a Prostrate Stone.*

The fallen sarsen stone chosen for examination this year is one of a group of five (two standing, three fallen) forming the south and south-west portion of the southern of the two inner circles. It is the most southern of the remaining prostrate stones of this circle, at a distance of 144 feet to the north of the most western of the two standing-stones near the entrance. Before excavation the stone was seen to have fallen in a southerly direction, the north end being considerably covered by turf. The digging was carried down to the solid chalk on all sides except the south and south-west.

This digging proved (1) that the stone measured $16\frac{1}{4}$ feet long by 12 feet wide; (2) that it had fallen in or since mediæval times; (3) that a socket-hole had been cut into the solid chalk to a depth of 1·5 foot, roughly shaped to receive the base of the stone; (4) that for additional support the stone had been packed round with a considerable number of blocks of sarsen measuring from 4 inches to 16 inches across; (5) that the base of the stone had been set at a depth of 4·3 feet from the present surface of the field; and (6) that the base of the stone in its fall had kicked out in a northerly direction only to the extent of 2 feet.

A number of shards were found in this excavation, but nothing was apparently of earlier date than Norman times. Between the surface and a depth of 2·5 feet, and above the level of the socket-hole cut into the solid chalk, this mediæval pottery appeared to be plentiful enough to indicate the former existence of some kind of a dwelling close against the stone, and it is possible that shelter for a number of years together may have been taken in close proximity to these huge standing-stones. Some of the pottery was found under the north end of this prostrate stone; it was, however, observed that the shards were close against the stone, and none below the level of the natural bed of the solid chalk.

A scale plan and two sectional diagrams were made of this excavation.

VI. *Animal Remains.*

Last year were found the remains of ox (of two sizes), horse (of two sizes), sheep, red-deer, ? roebuck, pig, dog, fox, ? wolf, and fowl. Some of these were kindly identified by Mr. E. T. Newton, F.R.S.

Besides the red-deer antler picks and the shovels of *scapulæ* previously recorded, the following animal remains were found this year:—

Cutting II.

Ox.—Humerus, depth, 6·3 feet in Roman stratum; tibia with ends missing, depth, 9·5 feet in Bronze Age stratum; part of radius of a young animal,[1] depth, 18·5 feet on bottom of fosse; metacarpus of large ox (length, 240 millimetres; estimated stature, 4 feet 9 inches), depth, 7·5 feet in Roman stratum; two digits,[1] depth, 7 feet.

Red Deer.—Two pieces of tine of antler, depth, 8 feet in mixed silting (No. 121 in section); smooth piece of tine of antler, depth, 10·2 feet at bottom of mixed silting (No. 127 in section); part of a metacarpus,[1] depth, 9 feet.

Mole.[1]—Scapula and sternum; depth not recorded.

Toad.[1]—Ilium; depth not recorded.

[1] Identified by Mr. E. T. Newton, F.R.S.

Cutting III.

Three teeth of horse; depth, 9·5 feet in Roman stratum.
Astragalus of ox; depth, 9·5 feet in Roman stratum.
Digit of red-deer;[1] depth, 11·5 feet in mixed silting.
Scapula of sheep;[1] depth, 18 feet in chalk rubble.
Lower jaw of dog,[1] smaller than a retriever; depth, 4·5 feet.

VII. *Concluding Remarks.*

The season's work, considering its short duration of three weeks for an undertaking of such magnitude, has in many respects been more interesting and eventful than the opening excavations of 1908. The main results of 1909 embody (1) proof of the existence and position of an ancient entrance into 'the Temple' from the south, *i.e.* from the direction of the Kennet Avenue, and (2) a considerable strengthening of the evidence obtained last year towards solving the difficult problem of the date of construction of Avebury, or, at any rate, of the great fosse surrounding the circles. The finding of a worked flint knife with every appearance of great age and of typical Neolithic form on the bottom of the fosse, is, we think, almost sufficient in itself to assign Avebury to the Neolithic period, rather than to the early Bronze Age—to which period Stonehenge is referred on fairly strong evidence.

It is also necessary in considering date to draw attention to the position of the pottery of Bronze Age type, most of which occurred about half-way down in the accumulated silting, showing that it became deposited when the fosse had become filled to a considerable extent; and some of the early British pottery was found in the mixed silting immediately below the Roman stratum.

In addition to the knife the bottom of this vast fosse has revealed several picks of antler and shovels of bone to the exclusion of other tools, and although there is no reason why such implements should not be used in later times, those found at Avebury are of precisely the same type as those of undoubted Neolithic age discovered in some quantity at Cissbury, the Grime's Graves, and in the Neolithic pit at Maumbury Rings. We have now little or no hesitation in regarding the fosse of Avebury as being of Neolithic construction; but it would be highly desirable, if not advisable, to make one or two cuttings more into a fosse affording the variety of interest which the Avebury one does. It must have been a most imposing sight—never to be blotted out from one's memory—to see that stupendous fosse open to the bottom all the way round.

Now that we know the position of the southern entrance it would be highly interesting to excavate the rounded end on its eastern side. The beech-trees and the modern road would not be hindrances in this position, and it would be necessary only to remove some scrub and small bushes. The silting not being so high as in the parts already examined, and probably at no time under cultivation, the labour entailed in re-excavating this part would be proportionately less than in this year's cuttings.

It would also be desirable to prove whether an entrance-causeway exists at the north of Avebury; and there are other details to clear up in regard to the southern entrance. In the latter work this year we

[1] Identified by Mr. E. T. Newton, F.R.S.

were pressed for time, and were hindered in determining the exact width and form of the causeway throughout its whole length, and our work was also impeded by the plantation of beech-trees.

As far as the causeway could be examined, the top, found at an average depth of 1·7 foot from the surface, was about 24 feet wide. On either side the level of the solid chalk gradually receded as if sloping off to meet the upper margin of the walls of the fosse in the form of rough steps not always well defined. The brink of the eastern fosse was followed in two places only. On the west such obstacles as the wooden fence, the bank and hedge, and the road itself, prevented any exact determination of the manner in which the western fosse finished and the causeway began. However, the existence of the entrance-causeway is a proved fact, the portals to the central area being represented by the two great standing-stones of the outer circle still in their original position.

The vallum now remaining nearest to the causeway would appear to have obstructed the entrance-way from the Kennet Avenue, but this is not really so, for allowance must be made for the silting down of the material composing the vallum at its end, forming a talus, and for the fact that other beech-trees have been planted in this position, caused obstruction, and gathered round them a certain amount of decayed vegetable matter.

VIII. *Grants and Subscriptions.*

In addition to the grant of 30*l.* made by the British Association for the excavations of 1909, the following private donations and grants were kindly subscribed to the fund:—

	£	s.	d.
Society of Antiquaries of London	25	0	0
Lord Avebury, D.C.L., F.R.S. (1908–9)	20	0	0
W. M. Tapp, LL.D., F.S.A.	5	0	0
The Hon. John Abercromby, F.S.A. (Scotland)	5	0	0
Marlborough College Natural History Society	5	0	0
British Archæological Association	3	3	0
Mrs. Eustace Smith and Reginald A. Smith, F.S.A.	1	0	0
J. Challenor Smith, F.S.A.	0	10	6

And the following donations from the Wiltshire Archæological Society:—

	£	s.	d.
W. Heward Bell, F.S.A.	5	5	0
Sir Prior Goldney, Bart., C.V.O., C.B.	2	2	0
Lord Edmond Fitzmaurice	2	0	0
F. H. Goldney	2	0	0
N. Story Maskelyne, F.R.S.	2	0	0
G. J. Buxton	1	0	0

Notes and Queries in Anthropology.—Report of the Committee, consisting of Mr. C. H. READ (*Chairman*), Professor J. L. MYRES (*Secretary*), Professor D. J. CUNNINGHAM, Mr. E. N. FALLAIZE, Dr. A. C. HADDON, Mr. T. A. JOYCE, *and* Drs. C. S. MYERS, W. H. R. RIVERS, C. G. SELIGMANN, *and* F. C. SHRUBSALL, *appointed to prepare a New Edition of 'Notes and Queries in Anthropology.'*

THE Committee have continued the work of preparing the new edition of *Notes and Queries in Anthropology*, and expect to print and publish it in the course of the coming winter. Until the precise size of the new edition is determined by final revision it is premature to enter into a contract with a printer. The Committee have, therefore, incurred no expenditure on this head, and retain intact the grant made by the Association in 1908; but the whole of this grant will certainly be required, unless the new edition is found to be much shorter than the old one. The Committee therefore ask to be reappointed, with the balance in hand.

Anthropological Photographs.—Report of the Committee, consisting of Dr. C. H. READ (*Chairman*), Mr. H. S. KINGSFORD (*Secretary*), Dr. T. ASHBY, Dr. G. A. AUDEN, Mr. H. BALFOUR, Mr. E. N. FALLAIZE, Dr. H. O. FORBES, Dr. A. C. HADDON, Mr. E. SIDNEY HARTLAND, Mr. E. HEAWOOD, Professor J. L. MYRES, *and* Professor FLINDERS PETRIE, *appointed for the Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest. (Drawn up by the Secretary.)*

THE Committee have to report that, as no grant was received last year, and the balance in hand has all been expended, no additions to the collection have been made since the last meeting of the Association, as it is useless to accept prints for the collection if it is not possible to mount and store them.

The Committee, first appointed in 1899, have received nothing beyond the initial grant of 10*l.*, which has now all been expended. Over a thousand photographs have been received and mounted, while in addition to this other collections, numbering some three thousand subjects, have been registered, catalogued, and made available to students.

Anthropometric Investigation in the British Isles.—Report of the Committee, consisting of Professor D. J. CUNNINGHAM (*Chairman*), Mr. J. GRAY (*Secretary*), *and* Dr. F. C. SHRUBSALL.

ALTHOUGH the last report of the Committee was considered to be final as regards the method of anthropometric investigation, it was thought advisable to reappoint the Committee to act as an organising centre to promote the establishment of anthropometric investigation among all classes of the population of the British Isles. In this direction important work has been done during the past year.

In October last the Secretary, at the request of Dr. Rawson, the Principal of Battersea Polytechnic, instructed his medical officer in the method of carrying out measurements in accordance with the Committee's scheme.

The importance of installing anthropometry in public schools was brought under the notice of the Headmasters' Conference on February 10 last, and their co-operation was asked for. In reply, a letter, dated May 21, was received from the Secretary of the Headmasters' Conference Committee, suggesting the issue of a short circular explaining the items of information that it was most important to collect. In response to this suggestion a memorandum was drawn up and sent out by the Anthropometric Committee to the headmasters of 107 public schools. It is hoped that this action will result, in the course of time, in the general establishment of anthropometry in public schools.

Measurements are now being carried out generally under the direction of the medical officers of the education authorities, in primary schools, and in a certain number of provided secondary schools. But there is still a wide field among secondary schools for both boys and girls in which the Committee could do good work.

The 1908 Report of the Committee on anthropometric method has been issued as a separate publication by the Royal Anthropological Institute (price 1*s*. net). This will make the scheme of the Committee available, in cheap and convenient form, to all who propose to undertake anthropometric work, and will ensure the uniformity which is so essential to make the results of different measurers comparable.

The Committee recommend that they should be reappointed, with a grant of 5*l*. for printing or typing circulars, postage, stationery, &c.

Archæological Investigations in British East Africa.—Interim Report of the Committee, consisting of Mr. D. G. HOGARTH, (*Chairman*), Dr. A. C. HADDON (*Secretary*), Mr. H. BALFOUR, Mr. C. T. CURRELLY, Dr. H. O. FORBES, *and* Professor J. L. MYRES.

No practical steps have been taken this year with regard to field-work in British East Africa, but the Secretary has received from local Government officers information as to localities which it is proposed to investigate, and estimates as to the cost of the expedition and other details of a practical character.

Archæological and Ethnological Researches in Crete.—Interim Report of the Committee, consisting of Mr. D. G. HOGARTH (*Chairman*), Professor J. L. MYRES (*Secretary*), Professor R. C. BOSANQUET, Dr. W. L. H. DUCKWORTH, Dr. A. J. EVANS, Professor A. MACALISTER, *and* Professor W. RIDGEWAY.

THE Committee have received the following reports from Mr. C. H. Hawes, who was able to return to Crete in the spring of 1909. In view of the important results outlined in this report, and of the possibility of a longer stay in Crete than Mr. Hawes originally contemplated, the Committee ask to be reappointed, with a further grant.

Report from Mr. C. H. Hawes.

Owing to the exigencies of printing and publication the present report has to be written at the outset of the expedition, and must therefore be an interim one. The report presented at the Dublin meeting last year resumed some of the results of a statistical study of the anthropometric survey made in 1905, and mentioned the lines of further research suggested by that study.

A piece of good fortune was met with at the opening of this season's work. During October 1908 four skulls, two portions of other crania, several pelvic and long bones came to light in the course of deepening a well in the alluvial bank of an ancient river ten minutes east of Candia. The argillaceous deposit in which they lay had acted as a natural plaster of Paris, and we are now in possession of human osseous remains of not later than the Middle Minoan III. period in the most extraordinary state of preservation. Complete measurements and observations have been made upon these, and I hope to publish them at an early date with a comparison of those discovered by Dr. Duckworth in 1903.

As I write I am about to set out for the small villages dotting the mountains which shut in to the south the richest and biggest plain in Crete, the Messara. Here and elsewhere in isolated mountain hamlets I hope to find the oldest element in the present racial mixture in Crete—the 'offscourings of the plains.'

In attacking the problem of how to discover or uncover the ancient stratum among the modern people, I have addressed myself to the task of finding out and isolating, if possible, alien elements of historical times. Representatives of Turkish and old Venetian families have been approached, and genealogical, traditional, and historical information garnered, with a view of testing it anthropometrically. For example, one village at which I am to stay this week claims to contain only descendants of Venetians who have strictly refused exogamous marriages. A small Armenian colony has existed in Candia since the Turkish occupation in 1669, and inasmuch as the Armenoid type of head is met with in the east end of the island, whether of historic or pre-historic date, this little band of settlers is being measured. Albanian influence has been suspected in Crete, and rightly so, since for various reasons the Turkish Janissaries in the island included large numbers of these Europeans, and considerable mixture resulted. In view also of the Dorian occupation of

Crete and the belief in certain quarters that Illyria largely furnished the Dorian hosts, it seemed important to get at the Albanian type. Records of these and other peoples to be met with in the island were in my possession, but I was anxious to attempt the method of race analysis by contours of the living head. During my short stay at Athens I was able, by the aid of Mr. Steele, of the Lake Copaïs Company, to pay a flying visit to an Albanian village in the mountains to the north-east of the lake. There, in the village of Martino, reputed to be the purest of five such, I measured forty individuals and obtained contours of their heads by means of an instrument which I had just completed.

It is as yet too early to speak of the value of this method of race analysis. Its advantage in sharpening and correcting visual impressions of head shapes is obvious; but I hope to be able to show after several months' test that a new weapon has been forged, with which to attack the very difficult problem of race analysis. Contours obtained at random from Albanians of the islands of Hydra and Spetza coincided exactly with the type from Martino.

The problem has been attacked from another direction. What modification of the cephalic index and the shape of the head has been effected by artificial deformation or formation of the head? I am indebted to Professor Macalister for calling my attention to the importance of this factor. It is a custom which is far more prevalent than is dreamed of, and thousands of people in this island, mostly of the male sex, are unaware of a custom which is universal except among the Mussulmans and the better educated minority of the urban population. As to the reason and methods of such head shaping, I hope to enter into details in a separate paper. The first object was to gauge the effect on the cephalic index and the contours. At the outset it is necessary to distinguish between the results of intentional formation and involuntary deformation due to the lying on hard surfaces. For these purposes I am making comparisons between subjects who have or have not undergone head shaping, and between those who have or have not suffered from a pillowless infancy. Striking examples of the latter are to be found among the small colony of Epirote bakers, who, owing to the extreme poverty of their parents at home, the circumstances of which I shall enter into more fully elsewhere, possess the most extraordinary and incredible head-shapes it has been my lot to see. Similar observations are being made upon the Armenian settlement here. Observations on these two extreme forms of head will prove instructive in comparison with the results of similar, though modified, treatment of the Cretan native. Further, whole families of Cretans are under observation, and measurements and contours have been taken of them, including children who have or have not been bandaged in their infancy, from the age of fourteen days up.

In addition to these researches, which are in progress, I have been able to garner from a cave, where are carelessly consigned the bones of many a deceased Cretan of to-day after a short burial in the cemetery, some hundred bones from all parts of the skeleton, saving, unfortunately, the cranium; and thus a comparison is possible between skeleton and skeleton of ancient and modern times. Two collections of hair, representing a series of shades, have been made for me by Orthodox and Mussulman barbers in Candia.

Crete appears to me to be a more than ordinarily instructive and significant field of research, and I hope that in the short time at my

disposal I may find answers to some of the many questions which open up at every turn.

Further Report from Mr. Hawes.

This report is made within a week of my return from Crete, and claims to be no more than a statement of the work accomplished and the material gathered.

I left England on March 24 of this year, and reached Athens on March 31, whence I visited the village of Martino, in the mountains to the north-east of Lake Copaïs, in order to get a series of measurements and head contours of reputedly pure Albanians for comparative purposes by a new process described below.

I landed in Crete on April 9 and remained on the island until July 18. Returning to Athens, a short expedition was made to Leonidhion, in the Peloponnesus, and England reached direct on August 5.

During the stay in Crete the remarkably preserved skulls and long bones belonging to the Middle Minoan period, recently discovered near Candia, were carefully and completely measured and compared with those previously discovered. For comparison with these, twenty-six skulls of nineteenth-century Cretans at the monastery of Arkadhi and twenty-eight skulls of eighteenth and nineteenth century Cretans at the monastery of Aghia Triadha, in Akrotiri, were measured and contoured. Four journeys on horseback, aggregating about seven hundred miles, were made for the purpose of measuring and contouring living subjects in special areas of the island; while every eparchy was traversed and sampled. Particular attention was paid to the highland peoples, and especially to those inhabiting the mountains to the south of the Messara plain, Sphakia and Lasithi. In the last case the various outlets were carefully tapped for comparison with the peoples above in the high land and those below in the plains.

Censuses of hair and eye colours were taken at schools throughout the island. In Candia and elsewhere the prevailing custom of the head-bandaging of infants was studied, and measurements, head contours, and photographs were taken of children of nine days old and upwards. Colonies of Armenians and Epirots were also included in my investigations. Finally a hundred photographs of various types were taken.

In all 1,693 persons were measured and about 1,650 contoured. Of these 1,576 were examined in Crete, but this number includes many foreigners. If we exclude all with known forbears from outside the island, as, *e.g.*, the Ægean and Ionian islands, and add the 200 records of Dr. Duckworth (1903) and my own 1,442 previous records (1905), we have in all, for the principal measurements, about 2,900 Cretan subjects represented. Of the 117 persons measured outside of Crete the majority hailed from Martino and Leonidhion, the latter, according to philologists, speaking the most Dorian dialect of Greek extant.

The most striking aspect of my anthropometrical work this year in Crete is the application of a new method of race analysis. I had only just completed before starting an instrument with which I intended to delineate the forms of living heads, and to pose these drawings in a scientifically comparable position. Though I have included among the head contours the transverse and the horizontal, I have finally relied upon the sagittal curve as the most significant.

The significance of this became apparent when, in experimenting

with Albanians of Martino, in North-East Greece, and others from the islands of Hydra and Spetza, I obtained practically identical contours, and when these again differed from the bulk of the Cretans. In Crete I frequently determined, to his astonishment, the local *provenance* of an individual merely by his contour. Speaking generally two types of head contour, strikingly distinct, are found in the island to-day, one associated with dolichocephaly and the other generally with brachycephaly. This latter type is found most commonly in Sphakia, a region naturally isolated, where the people are also less mixed, by reason of the custom of endogamy. By tradition and dialect the Sphakiots are more Dorian than the rest of the island. These types have connections outside of Crete which point north and west, but we stand badly in need of head contours for comparison.

It is obvious, if this method proves so rapid and incisive a criterion of race analysis in an island which, when all mean measurements are taken into account, is fairly homogeneous, that it might be applied with advantage over greater areas, where bigger contrasts are available. Further, it may enable us to determine the type or types of the prehistoric migrants. It bears testimony to the permanency of head form, in that, among others, a Late Minoan skull from Knossos is a type well represented among the nineteenth-century skulls at the monastery of Arkadhi. The problem of the origin and connections of the blue-eyed people of the higher altitudes of the Mediterranean and the greater problem of the connection between the short, dark dolichocephal of the Mediterranean and the tall, blonde dolichocephal of Northern Europe seems to me to await confirmation by this method. I have already made a beginning in measuring and contouring 161 foreign troops—French, Italian, and Russian—in Canea, but main types throughout Europe should in my opinion be contoured without delay.

The instrument referred to above will be more fully described and illustrated later, but a brief description is appended here.

The first portion, for obtaining the sagittal curve or contour, is a simple solder wire (half lead and half tin) one-eighth of an inch in diameter, cased in a rubber tube. This is found to be plastic, yet firm enough to withstand alteration in handling and posing. The instrument for posing the rubber-cased wire is of aluminium, and consists of two legs at right angles braced. These are scaled and pierced with slots, in which small square frames work. The frames hold false pencils, also scaled, which slide at right angles to the plane of the aluminium frame. At the angle, but exteriorly, is a detachable ear-piece, to insert in the auditory meatus.

The base-line adopted is that of the Frankfort agreement, and the object of this instrument is to determine the position of the curve in relation to this. The wire, having been shaped to the head, is left in position, and the instrument is held with the ear-piece in the ear-hole, and one leg pointing vertically and the other horizontally in the Frankfort base-line. Thus held it is only necessary to chalk the rubber where the legs cross it; but, as the legs, held at the side of the head, are at a distance from the rubber-cased wire in the median plane of the head, the false pencils are pushed through to meet it. The square frame and the false pencils can all be set to scale before applying to the head if the usual measurements have been already made on the head, or merely the breadth, the auricular altitude, and an additional auricular

radius to the point on the nose, where the extension of the Frankfort base-line crosses it. This method gives greater accuracy and saves time.

The chalk-marked wire is now ready to pose on the paper. The paper which is recommended is millimetre-ruled paper of about type-writer size, as supplied to schools. With plain paper it would be necessary carefully to place the instrument, withdraw the ear-piece, slide through the pencils, and mark the vertical and horizontal positions. With millimetre paper it is only required to read the scales and mark the paper accordingly. It is then a simple matter to pose the wire so that the chalk marks coincide with those marked on the paper, and to draw the curve, the rubber being found to cling well to the paper. The curve or contour thus taken begins in my examples at the inion and ends at the point on the nose crossed by the Frankfort base-line.

A description of this sort is naturally difficult to follow and gives a false idea of complication. I have found after some practice that the fitting of the rubber-cased wire on the head, the setting of the scales, and the posing and drawing, take on an average a minute and a half.

To obtain the transverse and horizontal contours the latter instrument is not required, the wire being sufficient. In the case of the horizontal contour, the position of the auditory meatus on each side should be chalked.

For a long time the need has been felt of something to supplement the cephalic index. In small areas or regions of comparative homogeneity, a less clumsy, more refined criterion is required, and I believe we have it in the contours of the head. The cephalic index was the result of the search after some mathematically comparable representation of the head form, but its most loyal adherents have felt the need of some more adequate description. A natural revolt was seen in Professor Sergi's methods and attempts at classification according to the pictured or observed head forms. There are, however, two obvious and important objections to the application of his methods to the living subject. First there is the drawback of the personal equation in descriptions of the shapes of heads, and secondly there is the impossibility in many cases—and this is a more serious objection than the layman would think—of getting a true visual impression of these shapes, covered as they are (and too often concealed) by hair. These two objections resolve themselves into one, and one which, I hope, the instrument I have described removes. It provides us with a means, until now wanting, of scientifically obtaining and recording the actual head-form of the living.

Archæological and Ethnological Investigations in Sardinia.—Report of the Committee, consisting of Mr. D. G. HOGARTH (*Chairman*), Professor R. C. BOSANQUET (*Secretary*), Dr. T. ASHBY, Dr. W. L. H. DUCKWORTH, Professor J. L. MYRES, *and* Dr. F. C. SHRUBSALL.

DR. DUNCAN MACKENZIE, honorary student of the British School at Rome, returned to Sardinia at the end of September 1908, and stayed there till the middle of November. He was accompanied for part of the time by

the director, Dr. Thomas Ashby, and by an architectural draughtsman, Mr. F. G. Newton, student of the school.

Their new observations have materially increased our knowledge of the two main groups of Sardinian megalithic monuments, the Nuraghi and the 'Tombs of the Giants.' The previous year's work made it clear that the former were fortified habitations. Dr. Mackenzie has now visited other examples and recorded variations of type and peculiarities of construction. The most remarkable is the Nuraghe of Voes in the Bitti district towards the north of Central Sardinia. Triangular in plan, it contains on the ground floor circular chambers with bee-hive roofs: the usual central chamber and one in each of the three angles. The entrance is on the south and leads into a small open court with a doorway at each side leading to the chamber at the base of the triangle, and another doorway straight in front by which the central chamber is entered. There was an upper story, now destroyed, reached by a stairway of the usual type. Exceptional features are two long curving corridors in the thickness of the wall on two sides of the triangle, intended probably as places of concealment. Above them were others of similar plan, but both series are so low that the roof of the upper one is level with that of the bee-hive chamber on the ground floor. This skilfully planned stronghold must have been built all at one time; other large Nuraghi were originally of simpler design, and have grown by the addition of bastions and towers.

A new type of Nuraghe was discovered at Nossia near the modern village of Paulilatino, in Central Sardinia. It is a massive quadrangular citadel of irregular rhomboidal plan with a round tower at each corner. These towers resemble the stone huts of the villages attached to some of the Nuraghi; they are entered from a central court-yard which here takes the place of the normal bee-hive chamber. It was partly filled with circular huts, so that this Nuraghe must be regarded as a fortified village rather than as the castle of a chieftain.

The dwellers in these Nuraghi buried their dead in family sepulchres popularly known as Tombs of the Giants. Several writers had suggested that these tombs with their elongated chamber and crescent-shaped front were derived from the more ancient dolmen type, but hitherto there was little evidence to support this conjecture, only one dolmen being known in Sardinia. Dr. Mackenzie has now made this derivation certain; he has studied ten important groups of dolmen tombs, most of them entirely unknown, which furnish a series of transitional types. In one case the chamber of an original dolmen tomb had at a later period been elongated so as to resemble that of a Giant's Tomb. In another example the large covering slab was supported by upright slabs at the sides and back; and behind it there are traces of an apse-like enclosing wall, such as is characteristic both of the Giants' Tombs and also of dolmens in certain localities where Giants' Tombs do not exist: for example, in Northern Corsica and in Ireland. Dr. Mackenzie also discovered a new type of Giant's Tomb in which the mound was entirely faced with stone, upright slabs being used below and polygonal work above. Another feature, hitherto unique, is a hidden entrance into the chamber at one side, in addition to the usual small hole in the centre of the front through which libations and offerings were probably introduced.

These results were described at a meeting of the British School at Rome in March 1909 (see 'Athenæum' of March 27). An illustrated report of them will appear in Volume V. of the Papers of the School,

Dr. Mackenzie and Mr. Newton intend to go to Sardinia, in September, for six weeks in order to continue the exploration of the island. The importance of anthropometrical work in connection with the problems presented by the early civilisation of Sardinia was pointed out in a previous report of this Committee. Mr. W. H. L. Duckworth, a member of the Committee, went to Rome last April and studied the collection of a hundred Sardinian crania in the Collegio Romano. He made about 1,200 measurements, and is preparing a report which will serve as a basis of comparison with any collection of ancient crania that may be obtained. In addition to these specimens, which had not been described previously, Mr. Duckworth has examined about thirty Sardinian crania in the museums of Rome and Paris. He has recently spent ten days in Corsica, where he obtained valuable illustrative material, and hopes to take part in Dr. Mackenzie's expedition to Sardinia in September next.

The Committee ask to be reappointed, and apply for a grant.

The Excavation of Neolithic Sites in Northern Greece.—Report of the Committee, consisting of Professor W. RIDGEWAY (*Chairman*), Professor J. L. MYRES (*Secretary*), Mr. J. P. DROOP, *and* Mr. D. G. HOGARTH.

THE Committee were appointed at Dublin, but received no grant: it was therefore impossible to undertake the proposed expedition to Thessaly. Those students of the British School of Archæology in Athens who had made the preliminary explorations reported at the Dublin meeting were, however, enabled by grants from the British School, and from the Liverpool University Institute of Archæology, to make excavations on fresh sites at Lianokladi and near the ancient Kierium. The results of these excavations will be published in the 'Liverpool Annals of Archæology and Anthropology' and in the 'Annual of the British School at Athens.

The Committee ask to be reappointed with a grant in aid of further inquiries in the same district.

The Ductless Glands.—Report of the Committee, consisting of Professor SCHÄFER (*Chairman*), Professor SWALE VINCENT (*Secretary*), Professor A. B. MACALLUM, Dr. L. E. SHORE, *and* Mrs. W. H. THOMPSON. (*Drawn up by the Secretary.*)

THE work has been divided as follows: Mrs. Thompson has continued her investigations upon the comparative anatomy and histology of the thyroids and parathyroids. Dr. Halpenny has been engaged in experimental work upon the same organs. Dr. Young has performed a further series of experiments of the same character as those which were reported last year by him and by Dr. Lehmann. Dr. Leeming and Mr. McKenty and Prof. Vincent have been occupied with the study

of the medulla of the adrenal body and the question of its relation to other similar tissues in the body.

Thyroids and Parathyroids.—Mrs. Thompson reports that all the evidence collected from a study of the thyroids and parathyroids throughout a wide range of the animal kingdom supports the view held by Vincent and Jolly, and by Forsyth—namely, that thyroids and parathyroids are not separate and independent organs, but are very intimately related. Within the thyroid of elasmobranchs are small, solid masses of cells, partly epithelial, partly adenoid. These, so far as we are aware, have not been previously described. In Teleosts there appears to be nothing corresponding to the parathyroid. The cells lining the thyroid vesicles are almost flat. In Amphibians the parathyroid is not in intimate relation with the thyroid. In Reptiles thyroids and parathyroids are anatomatically separate organs, but the parathyroid in some instances possesses distinct lumina, and the post-bronchial body secretes colloid. In Birds we frequently find large areas of the thyroid devoid of colloid vesicles (confirmatory of Forsyth). In Mammals there is much more intimate relationship between the parts of the thyroid apparatus than in the lower animals. The cells lining the vesicles are apparently of the same character as those accumulated in varying amount between the vesicles, which do not differ in any essential respect from those forming the parathyroid glandules. Many of the masses of intervesicular cells are indistinguishable from parathyroids. The internal parathyroid is frequently in direct tissue continuity with the thyroid and every kind of transition form exists. Parathyroid seems only to require colloid spaces in its interior in order to constitute itself thyroid, and this occurs in the human subject under certain pathological conditions. But thyroid and parathyroid are to be looked upon as structures of somewhat different embryological origin, which are totally distinct in the lower vertebrata, although coming into very intimate anatomical and physiological relationship with each other in the Mammalia. In this latter group they form, in fact, one apparatus.

Vincent and Jolly found that in the cat a parathyroid left behind after thyroidectomy changed its structure so as to approximate to that of thyroid. In the dog Dr. Halpenny has found similar, but more marked, changes in a parathyroid left behind after removal of the thyroid, and he also describes a case (see below) of the same kind of transformation in the rabbit.

Without denying that parathyroidectomy may be in itself fatal, Dr. Halpenny's experiments justify him in adopting the attitude of Vincent and Jolly that the operation is so supremely difficult (indeed, in the majority of cases, impossible) that the positive evidence on this point is far from convincing. It is certainly true that in many cases, when one performs the operation of total parathyroidectomy, doing as little damage as possible to the thyroid itself, the animals die quickly and with severe symptoms. But it is also the case that in many instances, when the operation has apparently been just as completely performed, the animals do not appear to suffer. This position has been reached after a large number of experiments, in many of which a complete histological examination was made of everything which was removed at the operation, and of all adjacent structures which were found on postmortem examination. This has involved the cutting of a large series of sections through the thyroid of animals which survived

parathyroidectomy. In some of these parathyroid tissue was found which had been overlooked at the operation; but it is important to note that in a few instances the animal died shortly after the operation, although two parathyroids were left intact.

It has been frequently stated that parathyroidectomy is not only essentially fatal, but that death occurs more rapidly than when the thyroids are removed in addition, and various hypotheses have been put forward to explain this phenomenon. In the present series of experiments death occurred earlier on the average with the complete operation than when parathyroidectomy alone was done, and in most of these cases the symptoms were those of violent tetany.

The experiments of Vincent and Jolly on the rabbit were few and inconclusive. In one respect our experiments entirely bear out the conclusions of the majority of workers on these animals—namely, that the animal dies in a few days if the whole apparatus be removed, thyroids and parathyroids together, but that it may survive for weeks or months if one or both of the external parathyroids be left *in situ*. Whether the animals may suffer from chronic symptoms resembling those of myxœdema in the human subject, cannot at present be certainly decided. It may be definitely stated, however, that no such chronic symptoms are noticeable after a period of three months. One rabbit, in which an attempt was made to extirpate thyroid and parathyroids *in toto*, survived forty-five days without symptoms, and was then killed. But at the postmortem examination shreds of glandular-looking tissue were found in the former situation of the external parathyroid, and these on microscopical examination showed distinctly the first stages of transformation into thyroid tissue. Nearly all the portions of parathyroid tissue revealed minute cleft-like spaces. In other portions of the tissue small rounded spaces, lined by a regular circle of cells, were to be seen, and in still other regions, especially at the edge of the parathyroid, were typical large colloid vesicles.

In another rabbit, which died forty-three days after removal of the thyroid with both external parathyroids left *in situ*, no changes had occurred in these glandules. It is tempting to suppose that it is precisely these changes in the parathyroids left behind which make a prolonged survival possible.

Changes in the pituitary corresponding to those described by Herring after thyroidectomy have been noted in the case of the dog after parathyroidectomy. This may indicate a functional relationship between parathyroid and pituitary.

Adrenals.—Dr. Young finds that, although on releasing ligatures which have been placed round the adrenal vessels there is a distinct rise of blood-pressure, yet during the period that the ligatures are applied there is no appreciable fall of blood-pressure. This is the case even after the lapse of several hours, with the blood from the adrenals absolutely excluded from the circulation. These experiments were performed upon dogs. Strehl and Weiss obtained a temporary fall on clamping the adrenal veins of the rabbit.

Paraganglion aorticum.—Mr. McKenty and Professor Swale Vincent have succeeded in displaying the ' paraganglion aorticum ' in several animals by the method of Stilling and Kohn, and a detailed microscopical study of this and kindred structures is being carried out at the present time.

Anæsthetics.—Interim Report of the Committee, consisting of Dr. A. D. Waller (*Chairman*), Dr. F. W. Hewitt (*Secretary*), *and* Sir F. Treves, *appointed to acquire further knowledge, Clinical and Experimental, concerning Anæsthetics—especially Chloroform, Ether, and Alcohol—with Special Reference to Deaths by or during Anæsthesia, and their possible Diminution.*

[Plates ix.–xiii.]

The Committee have held six meetings during the past year, and have in additon met informally on many occasions in the laboratory and at hospitals.

The following gentlemen have been co-opted members of the Committee: Dr. Buckmaster, Mr. J. A. Gardner, and Dr. Blumfield. Sir F. Treves, by reason of the pressure of other engagements, desires to retire from the Committee.

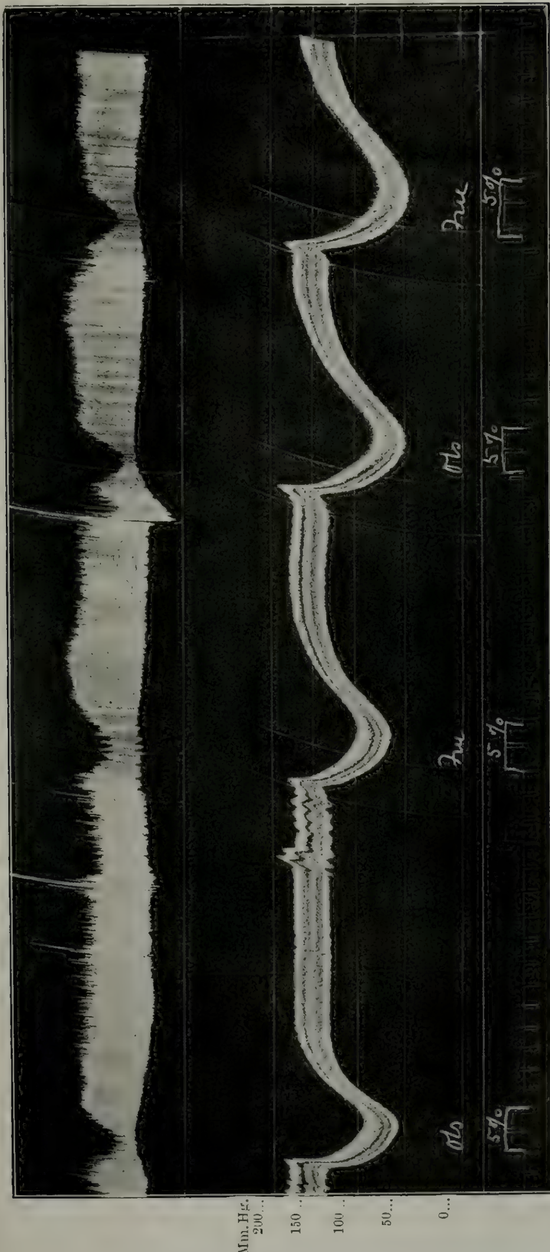
General Statement.

§ 1. We are agreed that while a skilful, careful, and experienced administrator can be trusted to secure anæsthesia of required degree with a minimum of risk, it is necessary to provide against accident at the hands of administrators who have not yet acquired experience, or who have not been educated so as to appreciate the power and danger of chloroform vapour.

This end can be approached by improved laboratory instruction concerning the physiological effects upon animals of chloroform vapour at known concentrations, and by the use of apparatus or other means of ensuring that the concentration of chloroform vapour shall be kept within given limits.

§ 2. Apparatus by which the percentage of the chloroform mixture offered to inspiration can be read off is especially valuable for educational purposes. As regards the use of apparatus for clinical use we prefer not to express any collective opinion at present.

§ 3. Another way of limiting the action of chloroform, by taking its vapour from a mixture of chloroform and ether (2 vols. chloroform + 3 vols. ether) has formed the subject of clinical investigation by Drs. Hewitt and Blumfield. The results of that investigation are given in



Effect of four successive administrations of chloroform vapour at 5 per cent., with respiration as free as possible, and obstructed by compression of the tracheal tube. The cat was in anæsthesia throughout the observation. Each of the four administrations lasted for as nearly as possible 2 minutes. The fall of carotid blood-pressure (lower line) occurring at each administration does not differ in the cases of free and of obstructed respiration. (The upper line gives the movements of the abdomen, indicative of the amplitude of respiratory movements.) Time is marked in minutes.

Illustrating the Report on Anæsthetics.

A simultaneous record (1) of the percentage of chloroform administered to a cat until cessation of respiration; (2) of the respiratory movements; and (3) of the carotid blood-pressure.

Illustrating the Report on Anæsthetics.

Appendix I. In this connection Mr. Symes has estimated the percentages of chloroform vapour aspirated from the inner surface of a bottle containing a mask upon which were poured equal volumes of (1) chloroform, (2) chloroform and ether mixed, and Dr. Waller has compared the relative toxicities on muscle of solutions of chloroform and ether mixture and of chloroform alone (Appendix III.).

§ 4. The relative toxicities of chloroform and of ether have been systematically estimated by Dr. Waller by a new method and compared with that of ethyl alcohol. The method and its results are described in a communication to the Royal Society. According to those results 1 vol. of chloroform is physiologically equivalent to 15 vols. of ether (or by weight 1 gramme chloroform = 8 grammes ether).[1]

Otherwise expressed, the physiological effectiveness of 1 vol. of ether is 0·067 that of 1 vol. of chloroform, and 1 vol. of chloroform is physiologically equivalent to 2·3 vols. of a mixture of 2C+3E.

§ 5. We are agreed that obstruction to respiration, whether by occlusion of the air passages or by the additional resistance offered to respiration by apparatus, should be avoided or promptly remedied. We therefore deprecate the use of apparatus based on the vacuum principle by which the patient aspirates anæsthetic vapour by means of a closed mask and tube, and consider it essential to any form of apparatus that it should be based on the plenum principle, by which an excess of anæsthetic vapour suitably diluted with air is propelled to an open mask by mechanical means sufficient to maintain a slight positive pressure at the end of the delivery tube.

In this connection we think proper to quote two experiments (representative of many others):—

§ 6. *First Experiment.*—The number of respirations per minute were taken of a member of the Committee breathing through a closed mask and a broad 1-inch tube:—

A with the end of the tube free.

B with the tube connected to the outlet of a balance case with the inlet connected to a force pump, working at between 10 and 15 litres per minute, giving at the mask a positive air-pressure equal to between 1 and 2 millimetres of water.

The normal respiration-frequency of the subject was 16 per minute.

The frequency under the conditions A quickly became 20, rose to 40, and culminated in dyspnœa, so that the mask had to be removed.

The frequency under the condition of B fell to 10 and 9, and the subject breathed from the closed mask for an indefinite time without feeling any inconvenience.

These results, in our opinion, sufficiently illustrate the ease with which dyspnœa can be produced in the human subject by slight obstruction and the contrary effect of air-supply delivered under positive pressure.

§ 7. The *second experiment*, on a cat, was made in order to see whether the toxic effects of chloroform were aggravated by obstructed respiration. The result was not in accordance with our expectation: no appreciable aggravation of toxic effect was caused by very considerable

[1] Since this report was adopted Waller and Symes, by a different method, have arrived at the same result, viz., 1 gramme chloroform = 8 grammes ether (see Appendix VI.).

degree of respiratory obstruction. We feel it necessary to report the result, although it contradicted our anticipation; the fact admitted of no doubt, whatever its explanation may be. The chloroform was of known identical percentage inspired from freshly filled bags of gold-beater's skin, and all other conditions of experiment except that of obstructed respiration were unaltered.

§ 8. The determination of the amount of chloroform in the blood of animals and of the human subject under various conditions of anæsthesia has been undertaken by Dr. Buckmaster and Mr. Gardner.

The results of a large number of determinations can be briefly summarised as follows: The amount of chloroform found in the blood during full chloroform anæsthesia was between 0·020 and 0·030 gramme per 100 grammes (by volume of vapour approximately 4 to 6 c.c. per 100).

The amount of chloroform found in the blood immediately after death by excess of chloroform was between 0·040 and 0·070 gramme.

§ 9. *General Conclusion.*—The Committee believe that the results so far obtained are of a nature that calls for the prosecution of the inquiry. The directions in which the Committee desire to proceed are: The further study (1) of the influence of obstructed respiration upon the course of anæsthesia, (2) of the physiological and clinical characteristics of mixed anæsthesia, and (3) of the physiological effects of local anæsthetics, such as cocain and allied substances.

APPENDIX I.

Report upon the Routine Use, by the Open Method, of a Mixture of Chloroform and Ether.

By Dr. F. W. Hewitt, *M.V.O.*, *and* Dr. J. Blumfeld, *B.A.*

1. *The Anæsthetic.*

The mixture is made of chloroform 2 parts by volume and ether 3 parts by volume. In hospital cases Duncan and Flockhart's methylated (red label) chloroform and Huskisson's 'pure methylated' ether were used to make the mixture. A similar mixture was usually employed in private practice, though in certain cases one with ethyl-alcohol constituents was used for purposes of comparison.

2. *The Method of Use and Apparatus employed.*

The mask employed (fig. 1) is essentially a Skinner's mask, and consists of a wire frame over which is stretched a single layer of thin flannel. The mask thus formed presents an oval opening 5 inches by 3 inches, and is capable of close adaptation to the face. The vault of the mask is high enough not to touch the nose when its rim rests upon the face. The size of the mask and the material with which it is covered are important details. It is found, for instance, that if two layers of the thin flannel are used instead of one an equal quantity of anæsthetic produces different effects in the two cases. The small tube passing through the middle of the stretched flannel is only of use when oxygen is required. A mask of the same dimnsions, but with a guttered rim, a handle, and no oxygen tube, has generally been used by one of us (J. B.). In using the mixture a gradual process is followed. The mask is applied to the face, and, after a few breaths, the mixture is added, a few drops at a time.

A regulating drop bottle is used capable of delivering the mixture in isolated drops, in a rapid series of drops or in a continuous stream (fig. 2). During the first two minutes the mixture is poured upon the mask in such small quantities at a time that there is never more than a quarter of the mask moist. From this time it is added more freely until, roughly

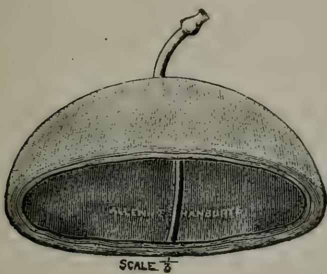


Fig. 1.

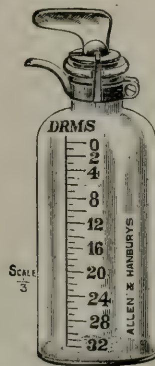


Fig. 2.

speaking, in the case of men the whole surface of the mask, in the case of women three-quarters of the surface, and in the case of children one half of the surface, is kept moist with the liquid. As a rule at least four minutes pass between the beginning of the administration and the moment when the maximum quantity to be used is upon the mask.

3. *The Nature of the Cases in which the Method has been employed.*

The cases in which the method has been employed include a variety of operations, comprising examples of almost all the graver abdominal procedures, which were particularly chosen as providing a severe test of the efficacy of any anæsthetic and method. Thus, pan-hysterectomies, removal of double pyo-salpinx, difficult appendicectomies, excisions of rectum, and 'complete' amputations of breast figure amongst the cases. Moreover, the patients comprised individuals of widely differing physique and states of health. They ranged from the very healthy muscular police-sergeant to that of the emaciated, anæmic young woman, the subject of long-standing colitis. Several so-called 'bad subjects' have been anæsthetised with success; for example, heavily built, florid, thick-necked men, with irritable throats and nasal obstruction, patients with ill-developed lower jaws, &c., subjects who invariably give trouble under 'gas and ether.' In age patients have ranged from the infant of fourteen months to old persons over eighty years of age. Several patients were markedly alcoholic, others were asthmatic and orthopnœic; one patient was suffering from pneumonia, and in this case oxygen was simultaneously administered through a tube passing through the mask. One case, that of a young woman who underwent laparotomy for the removal of double pyo-salpinx, was a good example of the subject who, originally favourable, is at the time of operation in a condition of extreme

feebleness from acute illness of some duration. Other examples of unfavourable conditions present in the patient were Graves' disease, acute bronchitis, and extreme anæmia. We have already conducted about three hundred administrations and are continuing to employ the method.

The preparation of patients has varied to some extent in the private cases. In hospital patients it was as follows:—

On the afternoon of the day preceding the operation a dose of castor oil, usually about an ounce, was given. On the morning of the operation (which took place after 1 P.M.) an enema was given at 6 A.M. Tea and bread-and-butter were given at 7—two slices and one cup. A pint of beef tea was given at 10. The enema was repeated if necessary.

4. *The Time required for inducing Anæsthesia and the Symptoms evoked during Induction.*

Time of induction is reckoned from the moment of commencement of inhalation to the moment when the patient is ready for the operation. That this point had been reached was judged by the presence of

(1) faint or absent corneal reflex;
(2) complete muscular relaxation; and
(3) presence of inspiratory stertor.

The average induction period in a series of hospital cases was 8½ minutes; the longest time spent in securing readiness for operation was 17 minutes; the shortest time was 5 minutes. With children 5 minutes was the rule, and this was the time also in the case of a woman very anæmic and ill with peritonitis. The longest induction period was in the case of a middle-aged carman, red-faced and accustomed to large amounts of beer, who had to be operated on for fistula in ano.

At the beginning of inhalation the vapour was not, as a rule, objected to, particularly if constituents made from ethylic alcohol were used. There is never any difficulty in getting patients to breathe freely. Excited talking becoming incoherent, or quiet busy muttering occurred in ten of forty hospital cases. Some rigidity of limbs and of jaw muscles occurred in eighteen of these cases. Excited movements of limbs or trunk, so forcible as to require restraining lest the patient should fall off the couch, occurred in one case. Excitement of the above kinds, when it occurred at all, was always after consciousness had gone—at any rate, to such an extent that the hearing was already quite lost. Secretion of mucus and saliva is not a feature of the induction stage with this anæsthetic. In difficult cases there is less temporary interference with respiration during the induction stage than when employing ether or 'gas and ether.'

5. *Amount of Mixture required.*

Generally speaking, it is found that in the case of an adult male the mask has to be kept moist over its whole surface after the first four minutes until full anæsthesia is induced. After this it is necessary to keep it moist to that extent only in the case of 'difficult' subjects. In the case of easier male subjects and in the case of women and of children only half of the mask is kept moist when anæsthesia is once established. In the case of children and women who are particularly feeble never more than half the mask is moistened from first to last and most

of the time only a quarter. In a series of hospital cases the average amount of the mixture consumed was an ounce in fourteen minutes:—

The least used was ½ oz. in twenty-two minutes (feeble infant).
The most used was 3½ oz. in thirty minutes (fat alcoholic woman).

6. *The Condition of the Patient during Operation and the Occurrence of Shock or other Reflex Effects.*

A condition which is highly satisfactory with regard to the state of the circulation, the respiration, the relaxation of muscles, and the immobility of the patient can almost invariably be obtained and maintained. Respiration is usually rather deeper, the pulse quicker, and the colour better than in average chloroform cases. The pupil is usually of moderate size. In one case only was a change of anæsthetic demanded. In this case, during the removal of a gall-stone a condition of persistent rigidity of the rectus led to a change from the mixture to ether (F. H.). In cases with marked respiratory defect the mixture can be given with oxygen. The type of anæsthesia obtained is more like that secured by low percentages of chloroform vapour than like that seen with ether. It is generally possible to secure a condition in which the corneal reflex is just present without the occurrence of inconvenient contraction of muscles or of coughing or retching. Reflex effects due to the operative procedure have been noted in several cases. Serious disturbance of pulse or of breathing arising in this way appears to be less liable to occur with this mixture than with pure chloroform, though more likely than when ether alone is given. Thus reflex effects during anæsthesia, chiefly bearing upon respiration, were evident in fifteen of seventy-five carefully recorded cases. In most cases these effects were in the nature of stridor, or of grunting expirations. They occurred during stretching of anal sphincter, forcible pulling up of uterus, internal urethrotomy, &c. The most marked instance of respiratory effect was produced by dragging upon the sac of a hernia, and this case afforded an excellent example of the degree to which such an effect can go, respiration becoming absolutely obstructed and the chest having to be compressed three times before breathing started again. At the same time the pulse scarcely showed any change. Reflex movements of limbs or reflex rigidities of muscle were very rarely met with, and this absence was particularly noticeable in rectal operations which, under ether, are frequently attended by such reflexes. Slowing of pulse as a reflex effect was occasionally observed. In a few cases well-marked pallor occurred during surgical manipulations. Severe surgical shock, resulting in disappearance of pulse, dilatation of pupils, opening of eyes, pallor, and stopping of respiration, was seen in one case in which laparotomy was being performed upon a thin anæmic young woman, the subject of extreme chronic constipation. The corneal reflex was faintly present at the moment when symptoms of shock suddenly showed themselves.

7. *After-effects.*

Speaking generally, recovery takes place rapidly and without any disagreeable after-effects, provided, of course, that the patient has been properly prepared. In no cases of our series were there severe after-effects. The worst instance was that of a case of removal of glands from

a young man of twenty-five years. In this instance there was vomiting seven times during the first fourteen hours after recovery of consciousness. Liquid nourishment was taken between the attacks of sickness, and there was no serious constitutional disturbance. In several cases there was vomiting once or more after recovery of consciousness. In one of these the vomit consisted of altered blood on the two occasions on which it occurred: this was a case of gastro-enterostomy. In practically all cases there was, twenty-four hours after operation, complete freedom from sickness and from feeling of nausea. Our belief is that after-effects are less common with this method than with most others now in use.

8. *Conclusions.*

Our experience leads us to believe that this mixture used in the particular manner described is a trustworthy and comparatively safe anæsthetic. By this we mean that if the simple principles are adhered to of starting gradually and limiting the moistened area of the mask overdosage is very unlikely to occur. It seems to us highly probable that the percentage of chloroform vapour thus offered to the patient is within the safe physiological limits. Moreover, the danger of post-anæsthetic lung complications which detracts from the otherwise safe nature of a similar ether anæsthesia is apparently no greater than is the case with chloroform. In our judgment the fact that even the most vigorous subject may be anæsthetised by this mixture on an open mask marks a distinct step in the progress of practical anæsthetics. The Rendle Inhaler, and all similar semi-open inhalers for the ACE or the CE mixture, should, in our opinion, now be discarded. The method described seems to us to contain the advantages of open etherisation with those of percentage chloroformisation, although, of course, it does not pretend to any absolute scientific accuracy so far as vapour percentages are concerned. By this method chloroform is rendered far safer than when administered *per se* on a Skinner's frame, and very much safer than when administered on lint or towel. We go so far, indeed, as to express the view that the administration of undiluted chloroform by means of lint, handkerchief, or towel should henceforth be proscribed in practice. The anæsthesia produced by this method is doubtless a chloroform anæsthesia in its essential features, but the dilution with ether renders it possible to present continuously a weak and comparatively safe chloroform percentage to the patient. Moreover, this mixture may, with the rarest possible exceptions, be used whenever chloroform itself is indicated. But it has advantages of another kind. It answers admirably and certainly far better than ether in so-called difficult cases, particularly in those liable to display symptoms of obstructed breathing during induction and in those in which the secretion of mucus would constitute a difficulty. As a substitute for the ' gas '-ether-chloroform sequence this mixture and method have much to be said in their favour. We have come to the conclusion, indeed, that some of the slight difficulties experienced by the anæsthetist in securing the most favourable surgical conditions during abdominal operations are often dependent upon the presence of small quantities of mucus within the upper respiratory passages resulting from the use of ether during the induction stage. Though rapid induction may be depended upon by ' gas and ether ' or similar methods before proceeding to chloroform or CE mixture, a

penalty often has to be paid, so to speak, for this rapid induction—viz., some disturbance in the smoothness of the subsequent anæsthesia. Although the method here advocated has the disadvantage of a comparatively lengthy induction, the eventual type of anæsthesia is highly satisfactory. In a word, we have no hesitation in recommending this mixture, administered by means of the particular mask and method we have described, as one which is capable of a wider range of applicability in general surgery than any other anæsthetic or mixture with which we are acquainted. Whilst the anæsthetic we have attempted to describe is undoubtedly safer than that produced by sprinkling undiluted chloroform upon lint, towel, or any form of open inhaler, we do not contend that it is safer, *whilst the patient is upon the operating table*, than ether anæsthesia. If, however, we take into account the risks of ether anæsthesia *after the operation*, we are of opinion that the method compares favourably with all known methods of etherisation, so far as safety is concerned.

APPENDIX II.

Description of the Chloroform Balance. By Dr. A. D. WALLER, *F.R.S.*

A closed glass bulb (capacity = 870 c.c.) is suspended from one side of the beam of an ordinary balance, the pointer of which shows 3 millimetres per centigramme, and is counterpoised at the other side of the beam.

The balance case (capacity = about 30 litres) is provided with inlet and outlet tubes, the former connected with a chloroform bottle through which a current of air (in this case about 15 litres per minute) is established by a pump or bellows, the latter connected with the mask or tube by which the mixture is delivered. The tube from the bellows or pump is provided with an elastic bag, and a constant stream of air of known volume per minute (10 to 20 litres) is secured by a perforated 'stop' fixed in the lumen of the tube; the chloroform bottle is provided with a regulating tap, by which all or none of the stream of air is passed through the chloroform bottle at will. The latter is graduated.

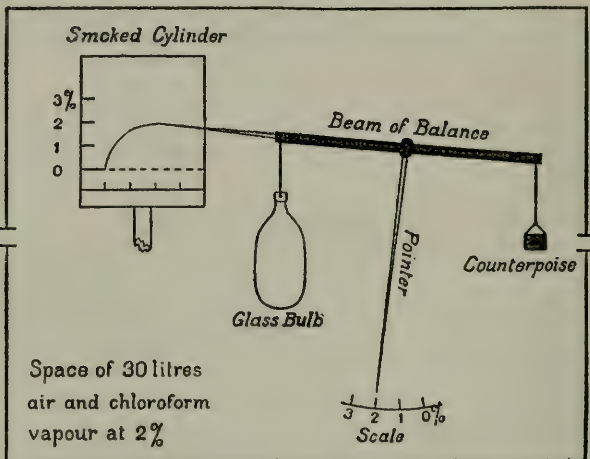
The percentage of chloroform (or of ether vapour if ether be used) is indicated by the pointer of the balance. It is at the same time recorded, if desired, on the smoked surface of a drum revolving once per hour (or per 12 hours), by means of a light pen fixed to the beam of the balance. This pen serves at the same time to damp the oscillations of the beam.

The calibration of [1] of the instrument is effected by means of weights corresponding to the weights of 1, 2, 3 per 100 of chloroform vapour in the volume of air represented by the bulb at ordinary temperature and pressure.

The zero of the chloroform scale is given by the position of the

[1] For the calibration at 18° C. and 760 mm. Hg of a chloroform balance in relation to the volume of a given bulb, divide the volume in c.cms. by 26·35; the quotient expresses the number of milligrammes that correspond to 1 per cent. of chloroform vapour, *e.g.*, for a bulb of 870 c.c. the corresponding weight is 870 : 26·35 or 33 milligrammes, and the scale of 1 to 3 per cent. is given by weights of 33, 66, 99 mgms. The effect of variations of temperature and pressure may be disregarded in this connection. The corrected values of 1 per cent. would be 1·017 and 0·983 at 23° and 13° respectively (*i.e.*, at 74°·4 and 56°·4 F.).

indicator point at the scale (and on the record) when the bulb is surrounded by air. If the indicator point at the scale is not opposite the zero marked there, the correspondence is secured by counterpoising or more simply by shifting the scale. At the temperature of 18 ± 10° the zero line would thus be lowered or raised by a weight of about 20 milligrammes (=rather more than 1 per cent. of chloroform), but the correction is not required, since it is made automatically.



Variations of temperature during observation would of course raise or lower the scale zero, but they are fortunately too trifling to be of account in the instrument shown. There is generally a variation of not more than ± 0·2 to 0·3°, implying a variation of weight of 0·4 to 0·6 milligramme, *i.e.*, 0·0235 to 0·0353 per cent. of chloroform. These are negligible corrections in the case of records taken by means of a 450 c.c. bulb with 1 per cent. chloroform at 18° and 760 mm. represented by 17 milligrammes of counterpoise and on the record by an ordinate of about 3·5 millimetres.

For finer observations with a delicate balance and a large bulb—870 c.c., and 1 per cent. CHCl, represented by 33 milligrammes—readings are taken by the null method on the pointer scale with an appropriate rider used as counterpoise; the estimation can then be made to an error of ± ½ or ¼ milligramme, *i.e.*, to an error of between $\frac{1}{66}$ or $\frac{1}{132}$ per cent. of $CHCl_3$. In this case of course the thermometer and barometer readings are taken into reckoning. But for all ordinary chloroform determinations temperature and pressure corrections are unnecessary.

The litre weight difference of ether vapour as compared with air (2020) is practically one-half that of chloroform (4045), so that the chloroform scale 1, 2, 3 per cent. is at the same time an ether scale 2, 4, 6 per cent.

APPENDIX III.

On the Physiological Effects of Mixed Anæsthetics.
By Dr. A. D. Waller, *F.R.S.*

In a paper recently presented to the Royal Society[1] I give in conclusion of a long series of experiments the following physiological equivalence of chloroform, ether, and alcohol: 1 c.c. chloroform =15 c.c. ether = 75 c.c. alcohol.

Adopting as a basis of calculation that the physiological power per unit of volume is therefore—

Alcohol	1
Ether	5
Chloroform	75

I proceeded to compare the effects of mixtures of anæsthetics with those of their constituents.

I found, in the first place, that the components of a mixture do not sensibly modify each other's effects. Taking, *e.g.*, the physiologically equivalent solutions—

Alcohol	75 c.c. per 1000 c.c. saline
Ether	15 " " " "
Chloroform	1 " " " "

I found that mixtures of these solutions produced about the same anæsthetic effect as did any one solution.

Taking next a mixture composed of equal parts of ether and chloroform, I found that its physiological strength was approximately one half that of pure chloroform, *i.e.*, that a 2 c.c. per 1000 solution of the mixture was physiologically equivalent to a 1 c.c per 1000 solution of chloroform alone. Theoretically, from the numbers given above, the equivalence should have been 1·88 c.c. of the mixture to 1 c.c. of chloroform, since the power of the mixture relative to that of chloroform is as 8 to 15. As a matter of fact, the 2 c.c. per 1000 solution of mixture had rather more effect than the 1 c.c. per 1000 solution of chloroform.

Similarly, with a mixture of equal volumes of alcohol and chloroform, in which the physiological power of the alcohol is relatively still smaller than in the case of ether, the action is still further reduced. In this case the equivalence should have been 1·97 c.c. of mixture to 1 c.c. of chloroform.

These observations show clearly that in anæsthetic mixtures composed of ether and chloroform, or of alcohol, ether, and chloroform, the principal anæsthetic power pertains to the chloroform, while ether and *a fortiori* alcohol act principally as diluents of the chloroform.[2]

Thus in the well-known ACE mixture, composed of 1A, 2C, and 3E, the shares of anæsthetic power of the constituents are A=1, C=150, E=15, the total power of the six volumes of mixture is 166, which,

[1] June 24, 1909.

[2] This is confirmatory of the statement I made in 1897 from experiments on isolated nerve, to the effect that 'the action of mixtures of ether and chloroform (7 parts of ether to 1 part of chloroform) is additive—the sum of the action of the two constituents of the mixture.' (*British Medical Journal*, November 20, figs. 20 and 21.)

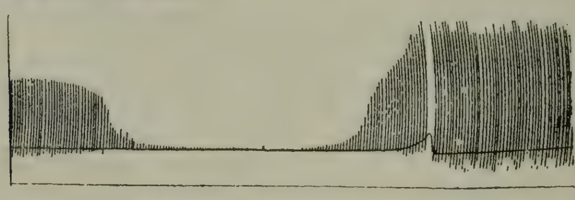
in relation to the power of six volumes $CHCl_3 = 450$, gives as the anæsthetic power of ACE compared with that of chloroform 166 : 450 or 0·37.

For a mixtue of two volumes chloroform with three volumes ether the similar value comes out as 165 : 375 or 0·44.

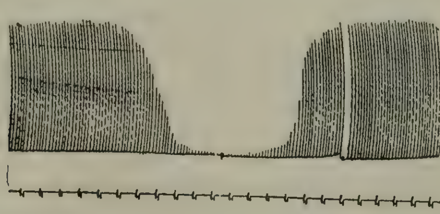
I proceeded to test these values by the experimental determination of equitoxic concentration of mixtures in relation to the toxicity of pure chloroform. And although the determinations have not been as numerous as I could have wished, owing to the fact that I had to make them myself and that my time is limited, yet they have given results that have been near enough to show that the method is sound.

Thus with 2·5 per 1000 solutions of the mixtures (2C+3E) and (1A+2C+3E) as compared with a 1 per 1000 solution of chloroform alone, I found that the first came out 'too strong' and the second 'too weak.' In terms of chloroform power taken as =1 the values of these two solutions =0·44 and 0·37, so that to make up their solutions to be equitoxic with a 1 per 1000 solution of chloroform I should have taken 2·3 and 2·7 c.c. per 1000 for the two solutions respectively. Considering that the excess and deficiency of 0·25 above and below these theoretical values 0·23 and 0·27 is only 0·02, and considering further the tentative character of those theoretical values, this result must be admitted to be very satisfactory. It affords further proof of the statement made above that the effect of mixed anæsthetics is the sum of the effects of the individual components.

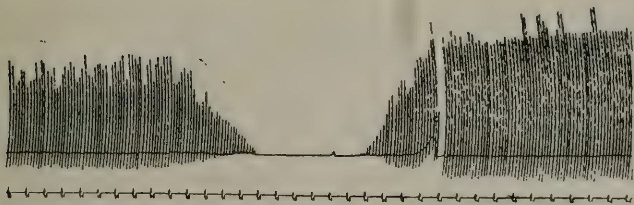
For all practical purposes I think it sufficient to say that I find the physiological efficacy upon muscle of an ACE mixture and of a CE to be approximately equal to that of $\frac{\text{chloroform}}{2\cdot5}$, the ACE being slightly weaker than the CE mixture.



Effect of a 2·5 per 1000 solution (by volume) in normal saline of the following mixture: (1 volume alcohol + 2 volumes chloroform + 3 volumes ether).



Effect of a 1 per 1000 solution (by volume) of chloroform in normal saline.



Effect of a 2·5 per 1000 solution (by volume) in normal saline of the following mixture:—

Chloroform	. . . . .	2 volumes
Ether	. . . . . .	3 ,,

N.B.—In each of these three records, reading from right to left, there are three groups of contractions, viz.:—

1. A group of normal contractions with the muscle immersed in saline.
2 A group of declining contractions with the muscle immersed in the test-solution.
3. A group of rising contractions with the test-solution replaced by normal saline.

APPENDIX IV.

The Comparative Power of Alcohol, Ether, and Chloroform as measured by their Action upon Muscular Contraction. By Dr. A. D. Waller, *F.R.S.* (*Royal Society, June* 24, 1909).

The object of the experiments described in this paper was to determine the relative physiological power upon muscular contraction of chloroform, ether, and alcohol at various dilutions.

The conclusion derived is to the following effect:—

By volume . .	1 c.c. chloroform = 15 c.c. ether = 75 c.c. alcohol
By weight . .	1 grm. chloroform = 8 grms. ether = 40 grms. alcohol
By molecules . .	1 mol. chloroform = 13 mols. ether = 100 mol. alcohol.

APPENDIX V.

Quantitative Estimations of Chloroform in Blood.
By J. A. Gardner *and* Dr. Buckmaster.

The Anæsthetic and Lethal Quantities of Chloroform in the Blood.—The method we have pursued in these experiments was as follows: In all cases the percentage of chloroform vapour in the inspired air was determined for each separate experiment. The amount of chloroform in the blood was estimated by the difference in chlorine-content of the blood before the administration of chloroform, and again at any subsequent period from the time when the chloroform-and-air mixture was inhaled. Numerous control experiments were made in order to ascertain whether the percentage of chlorine normally present in the blood of an animal remains sufficiently constant during a prolonged experiment. This was found to be the case when ether was the anæsthetic used. Small amounts of blood withdrawn from time to time during such an experiment were found to in no way affect the percentage of normal chlorine in blood. The chlorine was estimated by the method of Carius. A known weight of blood, about three to five grammes, is treated with nitric acid and an excess of solid silver nitrate in a bomb tube heated to 200° C. for six hours. The amount of resulting silver chloride was then determined, and the difference between

the chlorine-content of the blood before and after anæsthetisation with chloroform was calculated, and this gave a figure which could be expressed as chloroform. The whole method is an entirely new one, and has never been employed by earlier observers. In exactness it is believed to be preferable to those methods where the determination is a volumetric one with an end point which depends upon a colour reaction. Most of these experiments have been carried out on cats, while other observers have generally carried out their investigations on dogs. The chief conclusions arrived at were that the amount of chloroform in arterial blood at the moment when some definite reflex action disappears varies with different individuals. The same is true for the lethal amount in the blood; but a consideration of all the experiments taken together shows that only a narrow margin exists between the weight of chloroform in the blood at the moment of anæsthesia (loss of conjunctival reflexes) and the cessation of respiration (lethal amount).

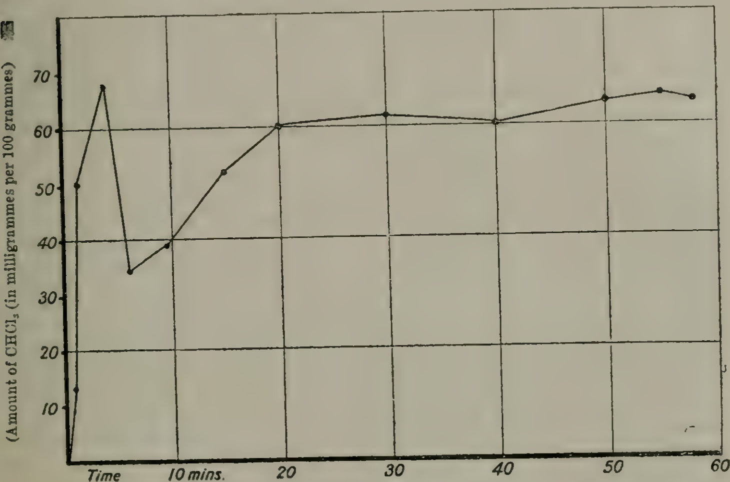
The conclusions are represented in the following table in comparison with the results of previous observers:—

Observer.	Animal.	Anæsthetic amount of $CHCl_3$. mg.		Lethal amount of $CHCl_3$. mg.
Gréhant and Quinquaud, 1883	dogs	50		—
Pohl, 1890	,,	18–50		35
Waller and Wells, 1903	cats	18		34
Nicloux, 1906	dogs	50		41–70
Tissot, 1906	,,	34–40		60–105
J. Mansion and J. Tissot, 1906	,,	29 32–43		—
Buckmaster and Gardner, 1906	,,	16–41	reflexes just gone	61–69
,, ,, ,,	cats	14–27·5	reflexes just gone	40

The Rate of Assumption of Chloroform by the Blood.—It is a familiar fact that when chloroform is inhaled the respirations may rapidly diminish in depth and frequency, or even actually stop within a few minutes. In the case of cats it is exceedingly rare not to see this effect on a respiratory tracing. Any individual animal may exhibit this phenomenon in different degrees, and cessation of respiration may be permanent unless resort is had to some means of artificial respiration. When the same animal is anæsthetised several times with the same percentage of chloroform vapour, this condition, which may be considered to indicate the first danger-point in chloroform anæsthesia, occurs at the same time, and presents a constant type of impaired respiration.

In our experiments, which were carried out on cats, small quantities of blood were withdrawn from time to time from an artery during the induction of anæsthesia with known percentages of chloroform vapour and air. The determination of the quantity of chloroform in these samples, ten or twelve in each experiment, afforded the data from which curves could be constructed. In all of the curves the same general features were seen. In the pre-anæsthetic period, or initial stages of anæsthesia, at a time when the individual is conscious, the chloroform-content of the blood rises with great rapidity to a value which approaches a maximum. During this period, which occupies the first few minutes, the first danger-point in anæsthesia occurs, because the quantity of chloroform in the blood directly or indirectly affects the respiratory nerve-centres of the brain. In consequence of

the respirations being slower and shallower, the amount of chloroform in the blood falls, but the fall is also due to the exit of the drug from the blood into the tissue-cells of the body. When the animal has passed this first stage the amount of chloroform again quickly rises



Plotted curve of the amount of chloroform found in the blood of a cat during the first hour of administration of chloroform at between 3 and 4 per 100 as determined by densimetry. (*Proc. Roy. Soc.*, vol. lxxix. p. 562.)

towards a maximum value, and an equilibrium between the factors which determine the amount of chloroform in the blood appears to be obtained, the processes of intake and output of the anæsthetic at the surface of the lung going on side by side. In other words, a state of equilibrium is reached, which persists for a considerable period, and throughout this period the difference between the amount of chloroform present in the blood and what is found at the lethal point is very small. The state is far from one of safety, and the animal may suddenly die at any moment should any disturbing factors come into play. The whole of this period is a danger period. In the experiments quoted the percentage of inspired chloroform was maintained constant, but it is evident that the contention of those anæsthetists who have insisted that after anæsthesia has been established this can be and should be maintained with a much smaller amount of chloroform vapour rests upon a sound basis.

The Function of the Red Blood-corpuscles in Chloroform Anæsthesia.—Experiments undertaken in order to ascertain how the anæsthetic distributes itself in the blood between the corpuscles and plasma proved to be exceptionally difficult. The separation of the corpuscles was accomplished by centrifugalising tubes of blood surrounded with ice, so as to hinder any clotting. Their conclusions, that chloroform is very firmly held by the blood of an anæsthetised animal, are in accord with all other observers. But it was also found that

chloroform primarily associates itself with the red corpuscles and does not enter the plasma to any marked extent unless the anæsthesia is pushed to an extreme degree, or a chloroform-and-air mixture is administered with a high percentage of the drug. After the inhalation of 2 per cent. chloroform for three-quarters of an hour no less than 98·5 per cent. of the anæsthetic was held by the red corpuscles.

In order to obtain additional proof that the red corpuscles, as would seem to be the case from experiments, are the essential vehicles for the carriage of chloroform, we argued that if the view was correct that the transport of chloroform was a function of the red corpuscles, then, though the absolute amount of chloroform present in the blood might be modified by abstracting or adding blood from or to an animal, the *percentage of chloroform* ought to remain constant.

The general plan of the experiments was to anæsthetise an animal with ether or nitrous oxide, allow the anæsthetic to be disengaged from the body, and then administer a known percentage of chloroform. The determination of the amount of the drug in the blood was made at the asphyxial point. In one hour or an hour and a half all the anæsthetic was eliminated, and during this period a measured amount of blood was abstracted and the experiment repeated. In other experiments the amount of chloroform present was determined in the same animal before hæmorrhage, after hæmorrhage, and after the replacement of the blood which was furnished from another animal in such quantity as to augment the original volume of the blood by one-third to one-half.

The general results of all the experiments were to the following effect:—

	Average amount of $CHCl_3$ per 100 grammes of blood. Before bleeding.	After bleeding.
Experiments in which the asphyxial state was rapidly reached, in about 3 to 9 min.	0·043 mg.	0·045 mg.
Experiments in which the asphyxial state occurred in about 30 to 80 min.	0·048	0·051

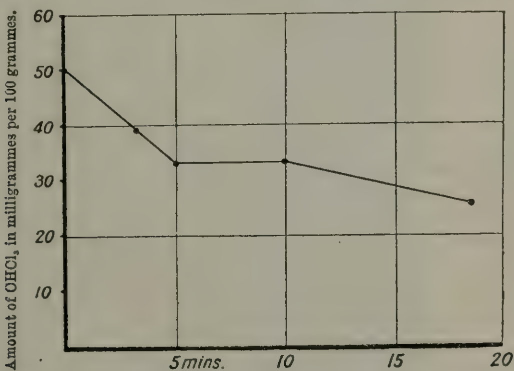
	After hæmorrhage.	After replacement of the blood.
Experiments made at the asphyxial point.	0·0421 mg.	0·0426 mg.
	0·0768 ,,	0·0768 ,,

	Before hæmorrhage.	After hæmorrhage.	After replacement of blood.
Experiments made at the asphyxial point.	0·061 mg.	0·059 mg.	0·049 mg.

The Rate at which Chloroform is eliminated from the Circulating Blood after Anæsthesia.—All observers are agreed that after the supply of chloroform is stopped the anæsthetic rapidly leaves the body. Thus, Nicloux found that the percentage in the blood five minutes after the cessation of chloroform inhalation had fallen to half its original amount during inhalation, and that at the end of seven hours the blood was quite clear of chloroform. Tissot gives, *e.g.*, the following numbers:—

	Milligrammes of $CHCl_3$ per 100 grammes of blood. Chloroform administration stopped.	45 min. later.	2 hr. later.
Arterial blood	53·2	5·8	0
Venous blood	48·1	7·7	4·9

In our own experiments, immediately the inhalation of chloroform stopped a sample of blood was taken from an artery, and this was repeated at intervals, until half or three-quarters of an hour had elapsed. In other experiments venous blood taken close to the right ventricle of the heart was examined in the same way, while in a few experiments samples of arterial and venous blood were taken simultaneously. The main conclusion which can be drawn from these experiments is that the rate of elimination of the drug from the body *viâ* the blood depends upon the physiological state of the individual animal. The rate of loss is at first comparatively rapid, and subsequently becomes slower. But the initial rates of elimination are much less rapid than the initial rates of the intake of chloroform, and, on the whole, elimination is a much slower process than assumption, a view which is supported, not only by the actual determinations of chloroform in the blood, but by a comparison of the times at which the various reflexes disappear and reappear. From our curves the initial falls are not quite so rapid as the work of other observers had led us to suppose.



Plotted curve of the amount of chloroform in the blood (arterial) of a cat during recovery from deep anæsthesia. (*Proc. Roy. Soc.*, vol. lxxix. p. 585.)

The chloroform-content of the blood was only reduced by 50 per cent. in fifteen to twenty minutes; three-quarters of the chloroform was eliminated in about half-an-hour. These statements hold good when the animal is breathing naturally, but, as might have been expected, the extent to which the lung is being ventilated during any period is the chief, if not the only, factor which determines the rate of elimination. Our experiments are in agreement with Tissot's observations: that at the moment when chloroform inhalation stops arterial blood contains an excess of the drug when compared with venous blood, but the difference between the amount of chloroform in arterial and venous blood after regular respiration is established is practically the same.

Percentage of Chloroform in Human Blood at the Stages of the Vanishing of the Corneal Reflex.—In order to ascertain whether the percentage of chloroform in the blood of man was of the same order of magnitude as in the blood of cats at a similar stage of anæsthesia, the following experiments were made: Three samples of blood were drawn by means of a syringe from the arm of a patient under chloroform at the point when the eye reflexes were just vanishing. The samples were taken within three minutes, and during this period the anæsthetist endeavoured to keep the patient at this stage.

The blood was analysed by Nicloux' method, with the following results:—

Sample I.	. . . .	0·0126 gramme per cent. of blood.
Sample II.	. . . .	0·0117 " " "
Sample III.	. . . .	0·0173 " " "

These figures are comparable with those found in animals.

APPENDIX VI.

The Comparative Physiological Power of Chloroform, Ether, and Alcohol, gauged by Intravenous Injection. By Dr. A. D. Waller *and* Mr. W. L. Symes.

Reckoning, from the observations quoted in Appendix V. (p. 307), that the average quantity of chloroform in the blood of fully anæsthetised animals is about 25 mgms. per 100 gms. of blood, considering further that 100 c.c. of saline solution can take into solution 500 mgms. of chloroform, it was to be expected that it should be possible to maintain complete anæsthesia by intravenous injection of saline containing chloroform in solution.

Taking, for instance, a 2 kilo. cat containing, say, 100 c.c. of blood, the injection of 10 c.c. of such 'chloroform saline' introduces into the circulation 50 mgms. of chloroform—*i.e.*, it is possible by this means to introduce no less than 500 mgms. of chloroform into the circulation, an amount far in excess of an anæsthetic or even a lethal percentage.

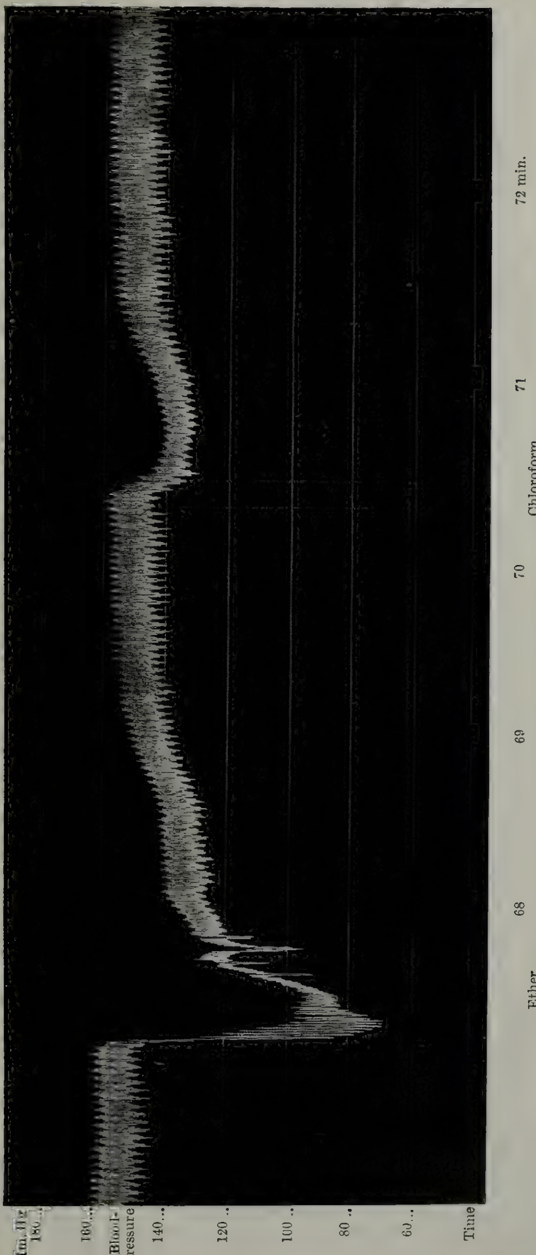
The possibility of inducing and maintaining anæsthesia by intravenous injections of emulsions of ether and of chloroform had, indeed, been shown by Arloing.[1] But considerations of convenience and precision led us to employ solutions, in spite of the greater dilution entailed.

For obvious reasons we could not induce anæsthesia by this means; we did so in the usual way by ether vapour, and the necessary preliminary operations, viz., tracheotomy and the introduction of cannulæ into the carotid artery and femoral vein, were carried out under full anæsthesia. From this point onwards anæsthesia was maintained complete by periodical injections into the venous system of 10 c.c. of 'chloroform (or ether) saline.'

In a first experiment a 3 kilo. cat was maintained in profound anæsthesia for two hours by fifteen such injections, containing a total amount of 750 mgms. of chloroform, *i.e.*, at room temperature, 150 c.c. of chloroform vapour.

Our object in adopting this method of anæsthesia was to institute a strict comparison between the effects of chloroform and ether and other

[1] Arloing, *Recherches expérimentales comparatives sur l'action du chloral, du chloroforme et de l'éther*, Paris, 1879.



Experiment No. 2, July 29, 1909. Cat 3·5 kos. Effect of ether and of chloroform on the blood-pressure taken by a mercurial manometer (10 c.c. ether saline containing 0·5 grm. ether, and 10 c.c. chloroform saline containing 0·05 grm. chloroform).

Illustrating the Report on Anæsthetics.

Experiment 3, July 30, 1909. Cat 2 kos. Record of the sixth chloroform injection (10 c.c. of 'chloroform saline' at 0·5 per cent., *i.e.*, 0·05 grm. chloroform) and of the sixth ether injection (8 c.c. of ether saline at 5 per cent., *i.e.*, 0·4 grm. ether).

Illustrating the Report on Anæsthetics.

anæsthetics, with precise knowledge of the actual mass of the anæsthetic introduced into the organism. The comparison of ether with chloroform introduced by inhalation is valuable and necessary, inasmuch as inhalation is the ordinary and regular means of introduction; but for an exact knowledge of the comparative effects of ether and chloroform at equal masses of the two drugs, inhalation is inadmissible, and it is necessary to proceed by intravenous injection.

The solubility of ether in saline—upwards of 8 per cent. at ordinary temperature—permits the employment of a solution of ether in saline at 5 per cent. by weight.

We used, therefore, a 5 per cent. solution of ether in comparison with a 0·5 per cent. solution of chloroform, *i.e.*, a mass relation of 10 grammes of ether to 1 gramme of chloroform (or a molecular relation of 16 mols. of ether to 1 mol. of chloroform).

In experiment No. 2 we noted that the injections of 10 c.c. of 5 per cent. 'ether saline' produced rather larger effects on the blood-pressure than did an equal volume of 0·5 per cent. of chloroform saline; but in this experiment we had not insured that the intravenous injections of 10 c.c. were made with equal rapidity, and we did not, as in our next experiment, systematically alternate the injections of chloroform and ether; we also noted in this experiment that the ether injections produced a greater effect on the respiratory movements than the injections of chloroform.

Experiment No. 2.—*July* 29, 1909. *Cat* 3·5 *kilos.*

Min.		Blood-pressure. Mm. Hg.	Fall of Blood-pressure. Mm. Hg.
14	Eth_1	145	25
18	Chl_3	160	15
32	Eth_3	150	50
35	Chl_6	155	35
52	Eth_4	160	120
55	Chl_9	135	25
67*	Eth_5	155	70
70*	Chl_{12}	155	20
90	Eth_{10}	150	100
93	Chl_{13}	140	30
98	Chl_{14}	145	25
101	Eth_{12}	140	70

Experiment No. 3.—*July* 30, 1909. (*Alternate injections of* 10 *c.c. of Chloroform Saline and Ether Saline.*)

Min.		Blood-pressure. Mm. Hg.	Fall of Blood-pressure. Mm. Hg.	Resp.
4	C_1	140	80	Diminution
8	E_1	100	70	Arrest
16	C_2	160	70	Brief arrest
23	E_2	150	70	Arrest (art. resp.)
27	C_3	170	80	Arrest
32	E_3	160	100	Arrest
41	C_4	150	80	Brief arrest
45	E_4 (8 c.c.)	150	80 to 110	Arrest
49	C_5	140	70	No effect
53	E_5 (8 c.c.)	140	70 to 90	Arrest
60†	C_6	130	90	Arrest
67†	E_6 (8 c.c.)	140	70 to 90	Arrest
74	C_7	140	90	Arrest
80	E_7 (8 c.c.)	100	Death	Permanent arrest

* See Plate XI. † See Plate XII.

During 80 minutes the animal had had injected into the circulation 70 c.c. of chloroform saline (0·350 gramme of chloroform) and 60 c.c. of ether saline (3 grammes of ether).

The effect of 0·5 gramme of ether was rather greater than that of 0·05 gramme of chloroform.

The effect of 0·4 gramme of ether was, as nearly as possible, equal to that of 0·05 gramme of chloroform—*i.e.*, by weight chloroform was found to be about eight times as powerful as ether. We proceeded to compare the effects of chloroform and alcohol, taking 'chloroform saline' at 0·5 gramme per 100 of chloroform, and 'alcohol saline' at 16 grammes per 100 of ethyl alcohol. Our anticipation was that approximately equal effects should be produced by the intravenous injection of equal volumes of these two solutions, and as a matter of fact our expectation was fulfilled by the following experiment:—

Experiment No. 4.—August 3, 1909. *Cat* 2·5 *kilos.*

Min.		Blood-pressure.	Fall of Blood-pressure.
4	C_1	150	50
6	A_1	150	50
9	C_2	150	50
13	A_2	140	50
18	C_3	100	40
22	E_1 (8 c.c.)	90	30 to 60
32	A_3	100	20
42*	C_4	100	30
45*	A_4	90	30

In this experiment the depressions of blood-pressure by what we had taken as physiologically equivalent injections of chloroform and alcohol were practically equal; we noted, however, that the alcohol depression was more gradual and more enduring than the chloroform depression. The ether depression was characteristically double.

Experiment No. 5.—August 5, 1909. *Cat* 4 *kilos.*

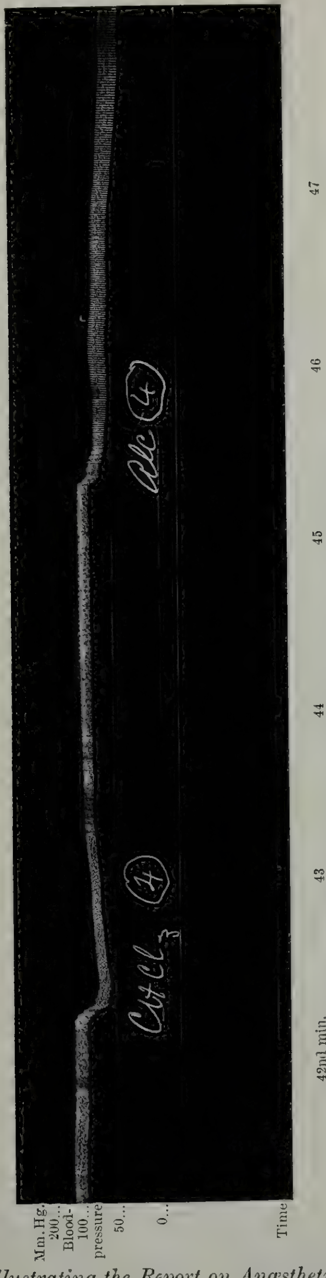
Min.		Blood-pressure.	Fall.
4	Chl_1 8 c.c. 0·040 gm.	200	50
6	Alc_1 10 1·600 „	200	80 to 130
13	Chl_2 10 c.c. 0·050 „	150	20
18	Alc_2 5 c.c. 0·800 „	150	10
20	Chl_3 10 0·050 „	150	30
		Death.	

Experiment No. 6.—August 6, 1909. *Cat* 1·3 *kilos; injections of* 5 *c.c. alcohol saline, ether saline, and chloroform saline.*

Time. Min.	Injection.	Blood-pressure. Mm. Hg.	Fall of Blood-pressure. Mm. Hg.
3	A_1	140	60
25	E_1	130	50
45	C_1	120	40
50	A_2	110	50
60	A_3	100	60
70	E_2	100	50
80	C_2	90	50

Further experiments will be required to bring out in detail, by the method of saline injections, the comparative effects of chloroform, ether, and alcohol (and other reagents). The examples we have quoted may, however, be taken as preliminary evidence of the mutually confirmatory

* See Plate XIII.



Experiment No. 4, August 3, 1909. Cat 2·5 kos. Effect of chloroform (fourth injection of 10 c.c. of 0·5 per cent. chloroform in saline) and of ethyl alcohol (fourth injection of 10 c.c. of 16 per cent. alcohol in saline).

Illustrating the Report on Anæsthetics.

character of the method of intravenous injection and of the sartorius method.

By the Sartorius method (Appendix IV.) one gramme of chloroform was found to be physiologically equivalent to eight grammes of ether and to 40 grammes of alcohol.

By the method of intravenous injection one gramme of chloroform was found to be physiologically equivalent to eight grammes of ether and to 32 grammes of alcohol.

The Electrical Phenomena and Metabolism of Arum Spadices.—*Report of the Committee, consisting of* Professor A. D. WALLER (*Chairman*), Miss SANDERS (*Secretary*[1]), Professor GOTCH, *and* Professor FARMER.

THE lines along which this investigation developed during the year 1907-08 led us to pay special attention to the general question of electrical response, and, in particular, to the question of transmission in vegetable tissues. In that connection it had been found that 'thermic stimulation' alone was capable of arousing an electrical response at a distance, mechanical and electrical stimulation being quite ineffective in this respect. This result was remarkable as being altogether opposed to the results of excitation in the case of animal tissues—nerve, muscle, heart. In these tissues, while the propagation of excitation, as indicated by its electrical signs, is quite clear, mechanical and electrical excitations are effective, whereas thermic excitation in its strict sense is exceedingly doubtful. This obvious opposition between the results in the two cases of animal and vegetable tissues led us to realise the very uncertain character of our knowledge concerning thermic excitation and the effects of heat upon the electrical state in animal as well as in vegetable tissues, and obliged us to undertake a far more extensive investigation than had been at first contemplated, viz., that of the effects of heat upon the electrical state of living tissues, animal as well as vegetable. To embrace the whole of this extensive field has, of course, been impossible. All that we could hope to do was to approach it at one or two promising points, at which we might expect to obtain positive data concerning vegetable tissues, which we have kept before us as our central point of attention. We have from time to time communicated, and when possible demonstrated, our results as regards animal tissues to the Royal Society and to the Physiological Society.[2] These results, as regards vegetable tissues, are given in the present Report, together with a summary of the papers referred to below.

The relative ease with which electrical response appears to be aroused in vegetable tissues by heat led us to retry under improved conditions of

[1] In the absence of Miss Sanders the duties of Secretary have been carried out by Mrs. Waller.

[2] No. 1. Do thermic shocks act as nerve-stimuli? *Proc. Physiol. Soc.*, January 23, 1909.

No. 2. Do thermic shocks act as muscle-stimuli? *Ibid.*, February 27, 1909.

No. 3. The effect of heat upon the electrical state of living tissues—muscle, nerve, skin. *Ibid.*, February 27, 1909, and in *Proc. R.S.*, March 1909.

experiment the question formerly put as to whether muscle and nerve are excitable by thermic stimuli. This retrial was all the more necessary in that, although the original publications of fifty and thirty years ago by Valentin, Eckhard, Pickford, and Grutzner give answers that are in substance in the negative, most recent text-books of physiology include 'thermic stimuli' in the list given of the various kinds of stimuli by which nerve and muscle can be excited. So that anyone coming fresh to the subject would be justified in assuming as a fixed datum of accepted knowledge that muscle and nerve can be excited by thermic shocks, whereas, as a matter of fact, the results of experiments, when first witnessed fifty years ago, were more than doubtful, and there is no subsequent sign in the literature of the subject to indicate that the experiments have ever been tried again; far less has any demonstration been given of either an affirmative or a negative answer to the question.

Paper No. 1[1] reports the experiments and results from which we draw the conclusion that the stimulation of nerve by the brief localised application of heat cannot be demonstrated by any regular effects in the muscle or in the galvanometer, the effects, if any, being irregular (and irreversible) and attributable to desiccation. Therefore the answer to our question, 'Do thermic shocks act as nerve stimuli?' is a clear negative. It need hardly be added that the answer applies solely to nerve fibres, and not to nerve terminations, and that it does not involve the well-known influence of heat upon excitability to ordinary forms of stimulation.

Paper No. 2[2] gives an account of experiments made in answer to the question, 'Do thermic shocks act as muscle stimuli?' It is more difficult to answer by a decided 'Yes' or 'No' to this question, because, on the one hand, muscle gives a contraction at each thermic shock that is to all appearance a 'sign of life,' in which case the answer is 'Yes,' and, on the other hand, altogether similar 'contractions' can be obtained on nerve that are assuredly not a 'sign of life,' in which case the answer is 'No.' The balance of probability is, therefore, that the answer is, as before, in the negative.

Paper No. 3[3] contains conclusions that we regard as being of very considerable general importance towards a comprehension of the chemical changes underlying excitatory effects in animal and vegetable tissues, and offers evidence of an opposition between the electrical effects of excitation and those of a brief application of heat.

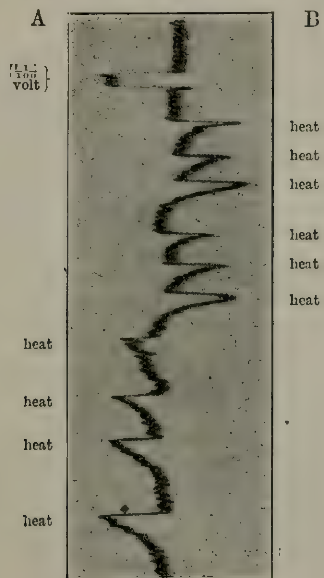
As regards animal tissues we investigated isolated muscle, isolated nerve, and isolated skin; as regards vegetable tissues we used pea and bean seedlings and the young fronds of maidenhair ferns. We commenced by observations on the sartorius muscle of the frog, repeating, under improved conditions of experiment, the observations of Worm-Müller and Hermann, whose results we considered to be inconclusive. The uniform result of our observations, from which the fallacy caused by thermo-electric currents was carefully excluded, was to the effect that the brief local application of heat (by means of a current of warm air) is to render the warmed spot 'anti-zincative' (galvanometrically positive) to any normal unwarmed spot; on repetition of the application

[1] Do thermic shocks act as nerve-stimuli? *Proc. Physiol. Soc.*, January 23, 1909.

[2] Do thermic shocks act as muscle-stimuli? *Ibid.*, February 27, 1909.

[3] The effect of heat upon the electrical state of living tissues. *Proc. Physiol. Soc.*, February 27, 1909, and *Proc.R.S.*, vol. 81 B., p. 303, 1909.

or by more prolonged continuous heat the warmed spot was rendered 'zincative' (galvanometrically negative). Thus the electrical effect of little heat—*i.e.*, of a comparatively small rise of temperature—is of the opposite sign to that of much heat—*i.e.*, of a comparatively large rise of temperature, and to that of injury; and we think there can be no doubt that the effect of much heat is in reality an effect of local injury, which, as is well known, is of the same electrical sign (zincative or negative) as that of the effect of local excitation. We note, therefore, as our conclusion that the first electrical effect of local heat is of



Effect of heat locally applied as described in the text under B (six times repeated) and under A (four times). In the first group B is rendered anti-zincative. In the second group A is rendered anti-zincative.

opposite direction to that of local excitation—*i.e.*, that the effect of moderate heat is anti-excitatory.

Similar experiments upon isolated frog's nerve gave similar results, from which we draw a similar conclusion confirmatory of the idea that the effect of moderate heat is anti-excitatory.

Similar experiments upon isolated frog's *skin* were particularly satisfactory. In this case the electrical effect of local excitation was to render the excited spot 'anti-zincative' (galvanometrically positive), and that of local moderate warmth was to render the warmed spot 'zincative' (galvanometrically negative). Thus, whereas the effects of excitation and of heat are of reversed sign upon the skin as compared with muscle and nerve, the electrical effect of local heat is, as in the case of muscle and nerve, of opposite direction to that of local

excitation. We have, therefore, as a general conclusion covering the three cases of muscle, nerve, and skin that *the effect of moderate heat is anti-excitatory.*

And we may refer back to the negative answers given to the question whether thermic shocks can act as stimuli to muscle. Obviously the fact that 'thermic shocks' give upon muscle and nerve electrical effects in opposite direction to that of the effects of excitation—*i.e.*, in an anti-excitatory direction—is in harmony with the conclusion that they do *not* act as stimuli to either muscle or nerve. The phenomena of heat-paralysis, moreover, which are apparently entirely non-excitatory, are in equal harmony with the conclusion.[1]

Similar experiments upon plants give results similar to those obtained upon muscle and nerve—*i.e.*, zincativity in consequence of local injury and local excitation; anti-zincativity in consequence of moderate local warmth. So far the identity of electrical effects in the case of animal and vegetable tissues is complete. The points on which identity is not complete relate (1) to the question of transmission, and (2) the question whether thermic shocks act as plant stimuli. We do not feel prepared to give a firm answer to this second question. On the side of a negative answer we have the fact that the electrical effect of moderate heat is in the anti-excitatory direction. On the other hand, the facts concerning transmission in which 'thermic excitation' was employed appear to imply an affirmative answer. Nevertheless, on weighing the probabilities of the case, we think it nearer the truth to speak of excitation by thermic injury rather than of thermic excitation proper, and we incline to the opinion that moderate heat in plants as well as in animals is anti-excitatory.

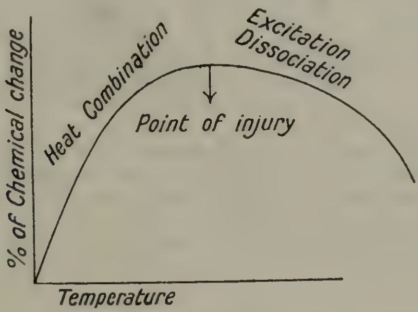
Note by Dr. Waller.—We find it difficult at the present stage to reconcile this conclusion with the undoubted fact that up to a certain limit the rate of chemical change is augmented by rise of temperature. It might have been anticipated *a priori* that sudden rise of temperature would arouse greater chemical action of the same character as that aroused by mechanical or electrical excitation, and therefore an electrical change of the same sign. As a matter of fact, however, the electrical change aroused by moderate heat, as stated above, has always proved to be of the opposite sign to that aroused by mechanical and by electrical excitation.

Note by Dr. V. H. Veley.—Dr. Waller has referred to me the difficulty set forth in the preceding note. The answer, as far as I am able to judge from the data, can be given as follows:—

Limiting our attention to muscle only, let us suppose a potential (and partial) chemical change, which becomes actual under slight variations of conditions, of a certain nature-stuff, called hereafter, for the sake of brevity, 'inogen.' Let us further suppose that this chemical change can take place in either of two directions, namely those of combination and of dissociation, being a simple reversible change of the type $X+Y \rightleftarrows XY$. Let us assume that such change is endothermal at a

[1] Brecht, 'Observations on the Nature of Heat-Paralysis in Nervous Tissues.' *American Journal of Physiology*, vol. xxii., September 1, 1908.

lower temperature and exothermal at a higher temperature, then its graph may be represented as under:—



The ascending portion of the curve represents chemical combination as induced by heat, the descending point chemical dissociation or decomposition induced by excitation, both, of course, being partial; the maximum point being that of injury or of initial excitation, as the case may be.

The graph corresponds to the more general diagram by which Dr. Waller has represented the effects of heat and excitation, viz.:—

Heat	←—	—→
Excitation or injury	—→	←—

Such chemical changes of the inogen, as represented in the graph, correspond to well-known chemical changes such as the formation or decomposition of hydrogen iodide from or into its constituent elements, or of hydrogen sulphide and hydrogen selenide (cf. Bodenstein 'Zeit. Phys. Chem.' 1899, 29, 295, 315, 429).

From this standpoint it is quite conceivable that the chemical (and electrical) effects of heat and of excitation respectively should take place in opposite directions. The observations given in the Report appear to indicate that this is actually the case.

The Effect of Climate upon Health and Disease.—Fourth Report of the Committee, consisting of Sir LAUDER BRUNTON (*Chairman*), Mr. J. BARCROFT *and* Lieut.-Colonel R. J. S. SIMPSON (*Secretaries*), Colonel Sir D. BRUCE, Dr. S. G. CAMPBELL, Sir KENDAL FRANKS, Professor J. G. MCKENDRICK, Sir A. MITCHELL, Dr. C. F. K. MURRAY, Dr. C. PORTER, Dr. J. L. TODD, Professor G. SIMS WOODHEAD, Sir A. E. WRIGHT, *and the* Heads of the Schools of Tropical Medicine of Liverpool, London, and Edinburgh.

THE Committee have received a number of communications from many parts of the world bearing upon various subjects of investigation. No progress has been made with the co-ordination of the data because

the work involves a considerable amount of clerical assistance, for which at present no provision exists. Researches upon the following subjects have been completed by individual members of the Committee:

(1) An analysis of the climatic conditions accompanying the incidence of epidemics of influenza in London in the past twenty years.

(2) One of the Secretaries, Lieut.-Colonel Simpson, C.M.G., has published the results of his investigations of the 'Effects of Heat in the South African War.'[1]

(3) The other Secretary, Mr. Barcroft, is now engaged on a study of certain conditions of the blood which influence respiration at high altitudes. These researches will be ready for publication, in part at all events, in the course of the ensuing year.

The Committee desire that they should be reappointed, and they ask for a grant of 15*l*.

The Structure of Fossil Plants.—Interim Report of the Committee, consisting of Dr. D. H. SCOTT (*Chairman*), Professor F. W. OLIVER (*Secretary*), Mr. E. A. NEWELL ARBER, *and* Professors A. C. SEWARD *and* F. E. WEISS.

MOST of the sections purchased are for Mr. H. H. Thomas's work on the structure of the leaves of *Calamites* and *Sphenophyllum*. He is obtaining interesting results, and his paper on the Calamitean leaves is likely to appear shortly, that on the leaves of *Sphenophyllum* following later. Little work has been done hitherto on the anatomy of these organs, as shown in the English coal measure material, and this investigation is likely to prove of considerable value from the point of view of physiological as well as of morphological anatomy.

The Experimental Study of Heredity.—Interim Report of the Committee, consisting of Mr. FRANCIS DARWIN (*Chairman*), Mr. A. G. TANSLEY (*Secretary*), *and* Professors BATESON *and* KEEBLE. (*Drawn up by* Professor BATESON.)

MY own experiments have consisted chiefly in continuation of the investigation of heredity in poultry, sweet peas, and some other subjects.

Miss Saunders has been for the most part engaged in experiments on the inheritance of double flowers in stocks and in several other genera.

Miss Killby has, as hitherto, assisted Miss Saunders in her work, and is undertaking a separate study of colour-inheritance in the annual phloxes.

The results attained in these several researches will be published in due course.

[1] *Journal of the Royal Army Medical Corps*, March 1909.

Clare Island.—Report of the Committee, consisting of Professor T. JOHNSON (*Chairman*), Mr. R. LLOYD PRAEGER (*Secretary*), Professor GRENVILLE COLE, Dr. SCHARFF, *and* Mr. A. G. TANSLEY, *appointed to arrange a Botanical, Zoological, and Geological Survey of Clare Island.*

WORK was begun at Easter 1909 when a party of nine members visited the island and the adjoining mainland, remaining for periods varying from five to nine days. Zoological, botanical, and geological work was carried out, special attention being given to land and fresh-water mollusca and to marine algæ. On May 15 a party of four proceeded to the island; birds, worms, and Muscineæ in particular being studied. They remained at work in the district for from one to three weeks. On June 8 a party of nine went to the island. The fresh-water fauna of the island and district (Crustacea, Rotifera, Hydrachnida, &c.) in particular was studied. Good collections of insects were also made. In addition to these organised parties, several other workers have been sent down separately, mosses, hepatics, and lichens in particular being collected. During July two parties, numbering in all fourteen persons, have been arranged for, and much collecting and observation will be carried out. In August a party of about fifteen will go down, and in September another party.

The greater part of the material collected has not yet, of course, been worked out; but some interesting plants and animals have been already recognised, including a number hitherto unknown in Ireland.

Mental and Physical Factors involved in Education.—Interim Report of the Committee, consisting of Professor J. J. FINDLAY (*Chairman*), Professor J. A. GREEN (*Secretary*), Professors J. ADAMS *and* E. P. CULVERWELL, Mr. G. F. DANIELL, Miss B. FOXLEY, Professor R. A. GREGORY, Dr. C. W. KIMMINS, Miss MAJOR, Dr. T. P. NUNN, Dr. SPEARMAN, Miss L. EDNA WALTER, *and* Dr. F. WARNER.

SIR E. BRABROOK, Mr. T. Loveday, Dr. Slaughter, Mr. Bompas Smith, and Mr. Twentyman have been co-opted upon the Committee.

The Committee have during the year been engaged in a preliminary inquiry as to the nature of the work that is at present being carried on, and as to the chief centres of activity.

The problems of education and instruction have been the subject of experimental inquiry of a sporadic kind during the whole of the nineteenth century, beginning with the work of Pestalozzi in Switzerland, who, in spite of defective equipment as a psychologist, endeavoured to lay the foundations of educational practice upon established facts of mind. He aimed at the discovery of formulæ, psycho-physical laws, as he called them, upon the basis of which text-books of instruction might be written;

and also advocated the establishment of institutions of pedagogical research, and of experimental schools, for which Kant himself had pleaded in still earlier days.

The connection of Universities with the problem goes back to the middle of the eighteenth century, when first Gesner and then Wolf established discussion classes for future schoolmasters in connection with their chairs. It was Herbart, however, who, during his tenure of the Chair of Philosophy and Pedagogy in Königsberg, made the *Pädagogisches Seminar* an essential feature of a German University, and a pupil of his, Stoy, founded what is still the most famous School of Pedagogy in Europe, if not in the world. For a time the reputation of another Herbartian, Ziller, made that of Leipsic still more important; but Ziller's death led to the abandonment of the most essential feature of such a Seminar from the Herbartian standpoint, viz.: the *Uebungsschule*. The University of Jena is now the only German University which maintains a permanent school in which the teaching of the Professor of Education may take a concrete shape, and where experimental work may be carried out.

In America and in England such schools have been established more or less on the Jena model. In Chicago an experimental school was established under the direction of Professor Dewey, and in England, thanks to the generosity of a private donor, the University of Manchester has been able to place the Fielden Demonstration Schools on a permanent footing. Important accounts of work done have issued from both these schools.[1]

Schools of this kind have usually been regarded as providing a field in which the general principles of education as taught by the Professor might take practical shape, not with the idea of attaining finality, but rather of showing ways in which principles might be applied, and of inspiring the students to fresh and varied effort in the application of them to the conditions of the ordinary schools. The existence of the school has naturally had a far-reaching effect upon the teaching of the Professor, who finds contact with reality a never-failing source of suggestion, as well as a testing-ground for the adequacy of his theories. In the main the problem of these schools is one of organisation in accordance with clearly conceived principles; their function is, on the one hand, to inspire students with a sense of the importance of basing teaching procedure upon rational grounds, and, on the other hand, to discover the necessary compromise between principles more or less abstract in character and the necessities of the practical situation.

Thanks very largely to the progress which has been made in experimental psychology, these schools are already in some cases serving a new cause—viz., the effort to base educational theory and practice upon ascertained facts in the physical and mental development of the child. It is difficult to appraise the work so far accomplished, but the Committee have satisfaction in reporting that wide interest has been already roused, and no mean volume of work has been placed upon record. They hope to deal with the subject in a later report.

Recognition is due to those experimental psychologists who, as individuals, have taken up this aspect of mind research, and contributed largely to securing the recognition of its importance. Amongst such men, Professors Binet and Henri in France, Professor Claparède

[1] The *Elementary School Record*, University of Chicago Press. The *Demonstration Schools Record*, University Press, Manchester.

in Switzerland, Professor Meumann and Professor Stern in Germany, Professor Van Biervliet in Belgium, Professor De Sanctis in Italy, Professor Stanley Hall in America, take a leading place. Whilst their methods differ fundamentally, all these gentlemen are experimental psychologists who have devoted themselves to inquiries of the greatest importance to the teacher.

In addition to the special interest of these particular professors, numerous institutions of a more permanent character have been set up in University and other centres. The Municipality of Milan has housed and endowed an 'Institute of Experimental Pedagogy,' under the direction of Dr. Ugo Pizzoli. The work of this institution was for a time recorded in its own journal, '*Bollettino di Pedagogia Sperimentale*.' The city of Antwerp maintains a pedagogical laboratory under the direction of Dr. M. C. Schuyten, who, in addition to the series of year-books regularly issued from his laboratory, is also responsible for researches which have been published in the '*Bulletins de l'Académie Royale de Belgique*,' '*Archives de Psychologie*,' &c. In Leipsic, the teachers of Saxony have founded, out of their own funds, aided by a State subvention, an *Institut für experimentelle Pädagogik und Psychologie*, with Privatdozent Dr. Brahn as its director.

The Russian War Office, curiously enough, has since 1904 maintained a laboratory for experimental psychology, with special reference to pedagogical questions. Here investigations are conducted and courses are delivered to audiences of teachers. The laboratory is now united with the Academy of Pedagogy, which was opened a year ago. Only students who have already graduated at some University are permitted to attend the courses. The Education Association of Moscow has opened a psychological laboratory, and the *Psychopädagogisches Institut* of St. Petersburg has undertaken an 'all-round' investigation of the daily progress of a number of children from birth to their twenty-first year, and upon the basis of observed facts it is proposed to fashion their education.

In Buda Pesth a State institution for research in this field was established in 1906, under the honorary direction of Dr. Ranschburg. It originated out of an effort to base the education of defective children upon a more scientific diagnosis of their condition, and its work now includes the investigation of the mental development of normal as well as of abnormal children.

In France Binet's interest has led to the foundation of a laboratory in close connection with a Paris elementary school in which the investigation of children's capacity and its development, both physical and mental, is continuously carried on.

In America the psychological laboratories of the Clark University under the guidance of Drs. Stanley Hall and Sanford, and of the Columbia University of New York under Dr. Cattell, are good examples of the tendency of the experimental psychologist to pursue problems genetic in character.

In addition to these institutions, attached for the most part to Universities, a number of societies for the scientific study of children have been active in recent years. Amongst these may be mentioned the following as typical:—

La Société libre pour l'Etude psychologique de l'Enfant, which, besides showing an interest in the work that is being done in various

centres, actually itself undertakes inquiries into problems of genetic psychology.

The *Child Study Society* of our own country, which is a federation of Child Study Societies in London and several large towns, publishes a quarterly journal, the '*Child Study*'; and, though somewhat different in character, the

Institut für angewandte Psychologie und psychologische Sammelforschung, of Berlin, which aims at becoming a centre of information for all interested in any branch of applied psychology.

As a further mark of the present-day importance of the work which the Committee have undertaken to investigate and report upon, we may note the great number of journals which are now largely devoted to the subject.

In addition to those already mentioned, there are in Germany:—

'*Zeitschrift für experimentelle Pädagogik*' (Meumann);
'*Zeitschrift für pädagogische Psychologie, Pathologie und Hygiene*' (Kemsies);
'*Zeitschrift für Kinderforschung*' (Koch, Trüper, &c.);
'*Pädagogisch-psychologische Studien*' (Brahn);
'*Zeitschrift für angewandte Psychologie und psychologische Sammelforschung*' (Stern);
'*Sammlung von Abhandlungen aus den Gebieten der pädagogischen Psychologie und Physiologie*' (Ziehen und Ziegler);
'*Pädagogische Monographien*' (Meumann);

in France:—

'*Année Psychologique*' (Binet);
'*Bulletin de la Société pour l'Etude psychologique de l'Enfant*' (Boitel);

in America:—

'*Psychological Clinic*';
'*Pedagogical Seminary*';

besides others in the Italian, Swedish, Spanish, Russian, and Japanese languages.

It is impossible in this report to put on record the many important experiments which are being carried out in schools in America, London, and elsewhere. These are isolated, and the Committee have not yet been able to get full information about them.

The value of the work that has been done cannot, of course, be measured by its volume. Some portion of it has probably little permanent value, because it has been done by persons who are not adequately trained psychologists or are not competent educational practitioners. The Committee feel with Dr. Spearman that 'the great need of the moment is the procural of facilities for research and the training of persons to direct it.' They would in this connection point out the need for public assistance. It is a new and important branch of research for which few, if any, British institutions are adequately equipped. They therefore ask the Sectional Committee to propose to the Committee of Recommendations that the Council of the Association should be authorised to organise a deputation to the Board of Education urging

the need of financial aid to Departments of Education in Universities and other higher institutions of learning, for purposes of research.

In conclusion, the Committee ask that they should be reappointed, and that a grant of 10*l.* should be made towards the cost of the inquiry. This sum would be chiefly expended in circularising foreign institutions and securing such literature bearing on the work that is being done as would enable the Committee to report more precisely upon the subject.

Corresponding Societies' Committee.—Report of the Committee, consisting of Mr. W. WHITAKER (*Chairman*), Mr. W. P. D. STEBBING (*Secretary*), Rev. J. O. BEVAN, Sir EDWARD BRABROOK, Dr. J. G. GARSON, Principal E. H. GRIFFITHS, Mr. T. V. HOLMES, Mr. J. HOPKINSON, Professor R. MELDOLA, Dr. H. R. MILL, Mr. F. W. RUDLER, Rev. T. R. R. STEBBING, *and the* PRESIDENT *and* GENERAL OFFICERS. (*Drawn up by the Secretary.*)

THE Committee beg leave to recommend that the Royal Institution of Cornwall and the Liverpool Botanical Society be placed on the list of *affiliated* societies. Applications have also been received from the Ipswich and District Field Club to be raised from the associated to the affiliated list and from the West Kent Natural History, Microscopical, and Photographic Society for affiliation, but the Committee has deferred its decision until further or sample parts of the proceedings of these two societies have been received.

The resignations of the Bakewell Naturalists' Club and the Haslemere Natural History Society as associated societies have been accepted by the Committee.

The Committee have had an enquiry arising out of the subject of photographic surveys, which was dealt with at the York and Leicester meetings, during the past year, as to starting a photographic survey of the County of Northamptonshire by the Northamptonshire Natural History Society and Field Club if the preliminary funds (about £12) could be raised.

Through the outcome of a clause in the resolution passed at the Leicester Conference that steps should be taken ' to found or promote a photographic record of the town or district in which the British Association holds its annual meeting,' the Committee are pleased to be able to state that an excellent exhibition of photographs, illustrating local natural history and archæology, was got together last year by the Dublin Naturalists' Field Club. The collection was shown in a room at Trinity College.

The Committee desire to bring before the Council the unofficial position of the Chairman of the Conference of Delegates. They suggest that he should be *ex officio* a member of the Committee of Recommendations, and therefore in a similar position to the Presidents of Sections.

Strong representations having been received as to the want of means for the publication of original work from which many scientific societies suffer, the Committee, with the consent of the Council, drew up a circular headed 'Suggested Publication Fund.' This has been sent out to all the chartered and local scientific societies not wholly given up to professional interests. By the end of July rather over forty acknowledging and detailed replies had been received to this circular. These have been partly considered and analysed, but the Committee await further replies and the result of the discussion at the Conference of Delegates before drawing up their report on the subject to the Council.

The Committee have decided to recommend that a discussion, introduced by Professor Meldola, on its 'Suggested Publication Fund,' should form a part of the business to be brought before the Conference of Delegates on October 25th and 26th. Special delegates have been appointed to join in this discussion. The Committee have also decided that the following subjects be brought before the Conference for discussion:—

'National Anthropometry: its object, methods and local organisation. Demonstration of methods of measurement.' To be introduced by Mr. J. Gray, B.Sc.

'The Financial Position of our Local Societies.' To be introduced by Mr. John Hopkinson (Watford).

Dr. A. C. Haddon has promised to preside at the Conference in London and to deliver an address to the Delegates.

The Committee ask for confirmation of the appointment of Mr. F. W. Rudler as Vice-Chairman and Mr. W. P. D. Stebbing as Secretary.

The Committee further ask to be reappointed with the additional name of Mr. A. L. Lewis; and they apply for a grant of £25.

Report of the Conference of Delegates of Corresponding Societies held at the Rooms of the Geological Society in London, October 25 *and* 26, 1909.

Chairman . . . A. C. Haddon, D.Sc., F.R.S.
Vice-Chairman . . F. W. Rudler, I.S.O.
Secretary . . . W. P. D. Stebbing.

Owing to the British Association meeting in Canada this year it was decided that the Conference of Delegates should meet in London, as was the case on the occasion of the South Africa meeting of 1905. The meetings were therefore held on the mornings of October 25 and 26, in the rooms of the Geological Society in Burlington House. Previously, on Sunday, the 24th, the Director (Lieut.-Col. David Prain, C.I.E., F.R.S.) and Dr. Stapf conducted a small party round the Royal Gardens at Kew; this was followed on Monday by a visit to the Natural History Department of the British Museum at Cromwell Road, under the leadership of Dr. A. Smith Woodward, Dr. S. F. Harmer, and Dr. G. T. Prior; and on Tuesday afternoon, by the kindness of the Council of the Zoological Society, a party visited the Society's gardens, and were conducted round by Mr. Seth Smith.

First Meeting, October 25.

The meeting was presided over by Dr. A. C. Haddon, Chairman of the Conference, who delivered the following address:—

Regional Surveys.

In all our societies there are various kinds of members, who have joined for very different reasons. The remarks which I am about to make are not intended to apply to the majority of workers. They for the most part know what they want to do and how to do it, and their time is usually fully occupied. There are, however, many members who are not workers; of these there must be a considerable number who accomplish nothing because they mistrust their own ability or do not quite know what to do. In other words, these members are interested, but not sufficiently interested. The problem is, how can their imagination be sufficiently stimulated to constrain them to set to work at something?

As men have diverse gifts so have they diverse interests. If our societies could manage not only to maintain the zeal of their ordinary working members, but to arouse the enthusiasm of fresh workers in old and new subjects, the societies would increase their membership and their efficiency, and the broader the basis of interest the more stable would be their position.

The widening of the interests need not lead to superficiality, for each worker can be as keen and deep a student of his own branch as his ability, time, and opportunities permit. The mingling of enthusiasts of different interests is alike stimulating and educative, and it is not loss of time to learn what others are discovering in or concerning the neighbourhood.

With all diffidence I venture to make a few remarks about certain subjects which appear to me eminently suitable for the more concerted study of the members of local societies.

The relation of geology to the present scenery has been the subject of innumerable books and memoirs, but there is yet room for more studies of the character of Principal A. W. Clayden's extremely valuable and interesting book, *The History of Devonshire Scenery: an Essay in Geographical Evolution* (1906). Our local societies can give valuable help in the collection of the details upon which generalisations of this kind are based, and those members who are interested in photography can supply the pictorial illustrations. I should like to draw attention to the paper on 'Charnwood Forest: a Buried Triassic Landscape,' by Professor W. W. Watts (*Geogr. Journ.* xxi. 1903, p. 623), as an illustration of the close connection between geology and geography. At the same time it affords an example of what can be done in a limited area by one who combines the gifts of seeing both minutely and broadly.

The study of geography has now been recognised as one of primary importance, not only for its own sake, but as a department of other branches of study. Fortunately, the teaching of geography has undergone a fundamental change since the days when most of us were at school, and from being largely an effort of memory has become a rational subject. The inter-relations of geography with other sciences render it peculiarly valuable as a starting-point or a meeting-ground, and the junior members of our societies should be encouraged to think geographically—if only the responsible persons in the Colonial and Foreign Offices could do so, much friction, ill-feeling, and loss would be saved to the Empire!

No better illustration of my meaning can be adduced than Dr. Hugh Robert Mill's admirable paper entitled 'A Fragment of the Geography of England: South-West Sussex' (*Geogr. Journ.* xv. 1900, pp. 205 and 353). Allusion may also be made to Dr. D. Woolacott's 'The Origin and Influence of the

Chief Physical Features of Northumberland and Durham' (*Geogr. Journ.* xxx. 1907, p. 36), and to a number of articles in the *Geographical Teacher* and the *Scottish Geographical Magazine.*

Nearly every district affords opportunities for geographical research, and guidance in such investigations is not lacking, as the Royal Geographical Society has of late years instituted a Research Department, one of the most important functions of which is to stimulate, direct, and criticise detailed local studies. In the summary of the work done during the last session it is stated that 'one important investigation is proceeding, namely, that upon the character of our coast, and its history as regards loss and gain, change of level, &c. But there are other objects which would repay attention, and among them may be mentioned the changes effected by rivers during historic times in the position and form of their beds, the change of level of the land now in progress from various causes, and the history of the names of fields, where these are of ancient date.'

Permit me to say a word about botany, or perhaps I should say local floras. While it is necessary to compile lists of plants growing in a district, these catalogues are apt to be as dry and lifeless as the actual specimens in a herbarium. Fortunately the living interest given to field-botany by the late R. Smith (*Botanical Survey of Scotland:* I. *Edinburgh District;* II. *Northern Perthshire,* 1900) has led to fruitful results, and the plant-ecologists who follow in his steps have done most excellent work, such, for example, as the following:—

'Geographical Distribution of Vegetation in Yorkshire,' by W. G. Smith and C. E. Moss, *Geogr. Journ.* xxi. 1903, p. 375, and by W. G. Smith and W. M. Rankin in *Geogr. Journ.* xxii. 1903, p. 149. J. G. Baker in his *North Yorkshire,* 1885, and F. A. Lees in his *Flora of West Yorkshire,* 1888, have adapted to Yorkshire Thurmann's attempt in 1849 to classify vegetation according to the mechanical constitution of the underlying rock; this was a step in advance, but modern ecology takes a wider view.

'Geographical Distribution of Vegetation of the Basins of the Rivers Eden, Tees, Wear, and Tyne,' by F. J. Lewis, *Geogr. Journ.* xxiii. 1904, p. 313, and xxiv. 1904, p. 267.

'The Vegetation of the District lying south of Dublin,' by G. H. Pethybridge and R. L. Praeger, *Proc. Roy. Irish Acad.* xxv. B. No. 6, 1905, p. 124.

'Peat Moors of the Pennines: their Age, Origin, and Utilization,' by C. E. Moss, *Geogr. Journ.* xxiii. 1904, p. 660, may be instanced as an investigation that has a more human aspect.

There still remain many areas in the British Islands where nothing of the kind has been done, but which will afford ample opportunities for local botanists.

Even in the well-worked subject of zoology there is much that can be done in addition to the record of the local fauna. There are numerous aspects of ecology that require to be studied. Even such a simple matter as whether birds eat butterflies requires further observation. It would not be uninteresting to record the faunal variations that occur from month to month in a selected sheet of water, or to note if the tributaries to a stream or river differ from one another as regards the facies of their respective fauna, and, if so, to seek for an explanation of the difference. The inter-relations of climate, soil, flora, and fauna present illimitable scope for study.

The Dublin Naturalists' Field Club has set a good example in its survey of Lambay, an island off the coast of County Dublin, and in that of Clare Island, now in progress, which might well be followed. The results of the former survey were published as 'Contributions to the Natural History of Lambay' in *The Irish Naturalist,* vol. xvi., January and February 1907, while those of the latter will be published by the Royal Irish Academy.

A fascinating and far-reaching subject is masked under the somewhat

repellent title of anthropogeography. This deals with the geographical distribution of man and the geographical control (as it is now so frequently termed) of man, his actions and works. Although much has been written on the effects of climate, geographical and geological conditions, and environment generally upon human occupations and settlement, there is yet a large field for the energies of local observers. Inquiries such as these are at the same time geographical, ethnological, archæological, historical, and sociological.

As an example of more strictly ethnological inquiries, permit me to refer you to a paper on 'The Ethnography of the Aran Islands, County Galway,' by A. C. Haddon and C. R. Browne (*Proc. Roy. Irish Acad.* [3] ii., 1893, p. 783), and to the subsequent papers by Dr. Browne in later numbers of the *Proceedings*. The subjects investigated were as follows:—I. Physiography, including the main geological and geographical conditions, climate, flora, and so forth. II. Anthropography, including statistics of hair- and eye-colour, physical measurements, vital statistics (population, acreage and rental, language and education, health), psychology, names. III. Sociology, including occupations, family life and customs, food, clothing, dwellings, transport. IV. Folk-lore V. Archæology (survivals, Christian antiquities, pagan antiquities). VI. History, &c. The methods of investigation, subjects studied, and mode of presentation of facts could be considerably improved; but I cannot but feel very strongly that we need investigations of this nature from every part of the country. Not only as regards savage and barbaric peoples, but also at home, our watchword should be the extensive study of limited areas. At the risk of appearing egotistical I may draw your attention to my *Study of Man* (London: John Murray, 1898), wherein numerous examples are given of various branches of ethnology which can be studied in our own country, and where I have also described some of the methods of ethnographical investigation.

There are signs that the value of studies of this nature is being recognised. A short time ago I read a review of a recent book by Jules Sion, *Les Paysans de la Normandie Orientale*, stating that 'this work endeavours to describe the physical environment as mankind found it in Eastern Normandy, and then goes on to trace the influences of that environment on the life of the inhabitants, together with the complex reactions of human activities on the characters of the district. . . . . The reader of this work will be tempted to hope that some day the local and provincial authorities of Britain may read studies of this kind, which would be invaluable helps towards working out an evolutionist and non-partisan policy for the healthy economic and social development of the districts under their charge.'

How detailed local study can elucidate history is exemplified in a suggestive paper entitled 'The Inclosure of Common Fields considered Geographically,' by Dr. Gilbert Slater (*Geogr. Journ.* xxix. 1907, p. 35), in which the author studies '"the extinction of village communities" or "throwing parishes into the melting-pot." These phrases imply that in places where *common fields*, as distinct from *commons*, are inclosed (1) there was, before inclosure, a definite survival from ancient times of the village community; (2) that such inclosure was a village revolution, a crisis in the village history, from which the village emerged with its social constitution materially altered. . . . . The inclosure of common fields is, it is clear, a feature of our national history, which needs to be viewed from the geographical as well as from the legal, agricultural, economic, and social points of view to be fully understood.'

Mr. Laurence Gomme's 'The Story of London Maps' (*Geogr. Journ.* xxxi. 1908, pp. 489, 616) indicates what may be done in a similar direction for other towns.

It is not possible to give every example of a local history on broad lines, but I should like to draw your attention to *The Evolution of the Ancient*

Town of Pickering in Yorkshire, by Gordon Home (London: J. M. Dent & Co. 1905).[1]

It would be advisable, if we could, to get more of the local photographic societies to work in harmony with other societies than is at present the case. They have their own proper functions, such as the interesting and training of beginners, the giving of demonstrations of various technical methods, artistic photography, and the like. There is, however, no reason why photographers should not co-operate with other workers and photograph scenery, geological sections, plant-colonies, folk-lore subjects such as old customs, old buildings, and other objects which are of interest for their antiquity or history, or which are in danger of destruction. By being pressed into this service they would assist their colleagues in other departments, and at the same time could follow out the special objects of a photographic society.

There are several counties which have a committee or society devoted to a photographic record survey. These need to be increased, and smaller units might be made, since possibly a regional photographic survey might appeal to more people than would a county survey; at all events the two are not mutually exclusive.

It would be presumptuous of me to offer you advice, but I would like to ask your consideration of the advisability and feasibility of local societies making it a part of their function to consider their area as a whole. By doing so they can attract new members and stimulate both the newer and the older workers. Wherever an individual's interest may lie, there is almost certain to be something of local interest that will appeal to him. There is plenty of scope for the usual type of field-naturalist and antiquary; at the same time there are new ways of regarding old subjects which need fresh workers. Even while details are being amassed there should always be kept in view the reasons for their accumulation. I should be the last to ignore the fact that all work that is worth doing necessitates a great deal of tedious labour; observations have to be made and remade, and the discipline of research must be regarded as one of its rewards; but, at the same time, the labourer should from time to time raise his head from his immediate work and look around him. Facts by themselves are liable to be but dull things; it is their interpretation that really counts. A heavily laden hulk makes very slow progress, and, on the other hand, a vessel with very little cargo but carrying much sail is liable to heel over. It is surely one of the functions of the Council of a local society to strike the balance between the two extremes. I would therefore suggest that those in authority in the local societies should definitely direct local effort. The results obtained by individuals or groups of workers would be published in most cases, I presume, in the Proceedings of the Society or in some other journal; but if they were reprinted in the local newspapers a great stimulus would be given to the intelligent teaching of geography and history in the schools, since immediate and actual facts are more interesting and impressive to most people than those that are remote, which must at the same time almost necessarily be vague.

Mr. William Dale (Hampshire Field Club and Archæological Society), in proposing a vote of thanks to the Chairman for his address, said the Conference was under deep obligation to Dr. Haddon, whose suggestions were most valuable, and who had shown a singular aptitude

[1] Since giving this address there has appeared a very valuable and suggestive book by Miss M. F. Davis, entitled *Life in an English Village: an Economic and Historical Survey of the Parish of Corsley, in Wiltshire* (Fisher Unwin, 1909). A work of this kind supplies invaluable data alike for the theoretical and practical economist, and while it may be profitably imitated by workers in other districts, each investigator would naturally vary the treatment of the subject according to his (or her) previous training and predilections and the character of the district.

for setting other people to work. He hoped that when the address was printed it would come forth in an enlarged form, and be read by all the Societies which were represented that day, as well as by those who were not. As an instance of the value of employing others, Mr. Dale said that his own large collection of prehistoric objects was formed largely through his teaching workmen who dig the soil what to look for. He hoped that each county in England would be able to find someone who would record the earthworks within its borders. He had succeeded in finding a worker who was now successfully scheduling those of Hampshire. He also said that, although the appointments on the Ancient Monuments Commission were not all that could be desired, it was the duty of the local societies loyally to assist that body.

Mr. F. A. Bellamy (Ashmolean N.H. Society of Oxfordshire) seconded the vote of thanks.

Mr. F. Balfour Browne (Belfast Naturalists' Field Club) was very glad that the subject of regional surveys had been raised, but he feared that the Chairman expected too much from the amateur. A survey of Lambay Island had been made, and another of Clare Island was in progress. Such surveys resulted largely in mere lists of species, and it was only the trained biologist who could make use of these. The amateur was doing very good work as a collector, and as a rule we should not expect more from him.

Mr. Hopkinson (Hertfordshire Natural History Society) spoke as to the importance of surveys, whether geographical or biological, being undertaken on a definite plan and by concerted action, and as to the false impressions which might arise from one district, be it a county or other division, having undergone thorough investigation, while others had been entirely neglected. At any time from about the year 1865 to 1890, he said, it might have been inferred from the recorded distribution of the Freshwater Rhizopoda in the British Isles that they were almost exclusively confined to Ireland; but as they have not been investigated there for the last thirty years or more, and have been assiduously collected in a few districts in England, Wales, and Scotland, Ireland would now have been far behind in the number of its known species had not he, in a few days' collecting in County Wicklow last year (September 1908), more than doubled the number hitherto known for the whole of the Emerald Isle.

A more striking instance of the misleading effect of isolated instead of concerted effort is that of our knowledge of the Diptera of Hertfordshire. In the British Museum there is a collection of about 1,000 species of flies from Felden, Boxmoor, not one-quarter of which are known to occur in any other part of Hertfordshire. The collection was formed by Mr. Albert Piffard, and in it there is only one flea, whilst the Hon. N. Charles Rothschild has found thirty species of pulicidæ at Tring, not one of which, except the Felden species (which is not *Pulex irritans*), has been recorded from any other part of the county. The list was published last year in the Transactions of the Society he represented, and although he did not think that Hertfordshire was particularly troubled with flies in general or with fleas in particular, he doubted whether any other county could show nearly so large a list of either.

In the discussion Dr. G. B. Longstaff, Dr. J. G. Garson, and Mr. H. D. Acland also spoke.

On the motion of the Chairman the meeting passed a hearty vote of thanks to the President and Council of the Geological Society for permitting the Conference of Delegates to meet in the Society's rooms.

The Secretary then read the report of the Corresponding Societies Committee to the British Association at Winnipeg.

The Secretary announced that the Rules of the Association had been amended so as to include the Chairman of the Conference of Delegates among the *ex officio* members of the Committee of Recommendations.

Mr. H. D. Acland (Royal Institution of Cornwall), as a matter on which

the Conference might express an opinion, suggested that the British Association should be the central body to encourage and direct local societies, that a circular should be sent to all such societies, whether in correspondence or not, suggesting that discoveries or original work should be reported to the British Association, and asking that schoolmasters and children and employers of labour should be desired to report any matter of interest to the local society.

Mr. F. Balfour Browne gave notice that he intended to bring up before the next meeting of the British Association a proposal that a committee of biologists should be formed to recommend the adoption of a definite system on which collectors should record their captures. The real use of the collectors' list is for the student of distribution, and if all the records were made on a definite system the regional surveys would be of definite use. The county and vice-county system, as laid down by H. C. Watson (*Cybele Britannica*), was probably the best, but there were several modifications of it used by different investigators, and it was necessary that some *one* form of it should be officially recognised. If this were done the regional surveys would be really valuable, and since all branches of biology would be worked on the same basis, the inter-relationships of the various subjects could be brought out.

Mr. John Gray (Royal Anthropological Institute) introduced the following subject:—

National Anthropometry: its Objects, Methods, and Local Organisation.

National anthropometry may be described, as far as we are concerned, as the study by exact measurements of the origin, racial composition, and evolution of the British nation.

A time comes in the history of every science when an attempt is made to measure the somewhat vague qualities with which perforce the infant science is content to deal. The qualitative science becomes quantitative. Such a change has already taken place in such sciences as chemistry.

The change has begun, though it is yet far from complete, in the science of anthropology. We may define anthropometry as *quantitative* anthropology.

We can measure with great precision the bodily structure of man, for example—his weight, height, head, and other anatomical dimensions—we can also measure with fair precision his physiological functions, such as the acuity of vision and hearing, tactile sensibility and muscular power; but a beginning has only just been made by the anthropologist in the exact measurement of the higher mental functions. These last promise to be the most important of all the departments of anthropometry.

The objects of national anthropometry may be roughly subdivided into—

Firstly, those of purely scientific interest, such as questions of the origin and racial composition of our people.

Secondly, those of more utilitarian interest, such as the present-day evolution of our people, and the probable changes that may be brought about by the new conditions of modern life.

The value of anthropometry in identifying the various racial elements in our population, in ascertaining approximately the epochs of their settlement in this country, and in determining their affinities with other races, may, I think, best be explained by shortly describing some of the results that have already been achieved.

It is now pretty generally accepted among anthropologists that the average physical characters of a people tend to remain constant for vast periods of time if there is no admixture with other races and no great changes of the environment. In Egypt, for example, it has been proved by measurement that the average head-dimensions of the peasantry have remained practically constant for some ten thousand years.

The ratio of the head-breadth to the head-length has been found to be a very valuable index of race. This, when expressed as a percentage, is termed the *cephalic index*, and races having a high cephalic index are said to be *brachycephalic*, those having a low cephalic index *dolichocephalic*, and those with a medium cephalic index *mesocephalic*.

In a map showing the geographical distribution of cephalic indexes among the various races of the earth it will be seen that the grand centre of brachycephaly is in the mountainous regions of Central Asia, and that it spreads with reduced intensity through Asia Minor and the Alpine regions of Central Europe. The native Indian tribes of America are mostly brachycephalic, while dolichocephaly is practically universal in Africa. In the south and north of Europe the populations are inclined to dolichocephaly.

These general facts give us a datum-line for the determination of the probable racial affinities of the prehistoric races of Britain.

I show a chart of the average head-dimensions of the known prehistoric races of Britain. The position of each race on the chart is determined by using its average length and breadth of head as a kind of latitude and longitude, the diagonal lines showing the cephalic indexes.

The earliest skulls found in Britain (with the exception of one solitary palæolithic specimen) belong to the neolithic or late Stone Age. This race is represented on the chart by two groups, one measured by Davis and Thurnam and the other by Schuster; both these groups are dolichocephalic. Following the neolithic race, at the beginning of the Bronze Age, a short hyper-brachycephalic race, with a cephalic index of 86, entered Britain. Knowing what we do about the stability of the physical dimensions of races, it appears to be impossible to believe that this race was derived from the neolithic race. Its nearest affinities, as far as is known, are with some of the brachycephalic mongoloid races of Asia.

Coming after this short hyper-brachycephalic race of the early Bronze Age we have a tall brachycephalic race of the later Bronze Age (the round barrow-men), which from its position on the chart may well be a blend of the two previous races. Then we have the Saxon type of the Iron Age, which closely resembles the modern Scandinavian type, as we should naturally expect from historical evidence.

Thus we see that where historical and anthropometric evidence overlap they agree. This gives us some confidence in the anthropometric evidence, which may fairly claim that it contributes an important part of the light that relieves the long night before the dawn of history.

Traces of these prehistoric races ought to be found in the living population of the British Isles, and, as far as measurements have been made, this is found to be the case. Comparatively few measurements of the living races have, however, been made, and this is one of the questions of the greatest scientific interest which would be solved by a National Anthropometric Survey.

If the Corresponding Societies were to undertake such a survey they might be able to tell us whether the cephalic index of the population is higher than the average in the districts where the hyper-brachycephalic skeletons of the early Bronze Age have been found—for example, in Wales and on the east of Scotland from the Forth to the Orkneys.

Again, we should look for a dolichocephalic type, tall and fair, in the regions which history tells us were conquered and colonised by the Anglo-Saxons. The extent to which these characteristic traits of the Teutonic or North European race have been modified will give a fair estimate of the amount of admixture with other races or of the influence of known changes of environment.

These illustrations may give you some idea of the immense scientific interest of extensive measurements of the living population.

The private enterprise of a few anthropologists has resulted in a somewhat superficial survey of some of the physical characters of our population. A map [1] of the distribution of stature in the British Isles has been prepared from data collected by the Anthropometric Committee of the British Association, but it should be noted that the map has been prepared from measurements of only 8,585 persons, a quite inadequate sample of a population of forty millions.

Dr. Beddoe has prepared maps of the hair- and eye-colours of the British Isles, which are undoubtedly of the greatest value, though the number of observations again are far from sufficient.

The scientific enthusiasm and patriotism of the school teachers of Scotland has enabled them to carry out a pigmentation survey of the children in the primary schools of Scotland. But all the anthropometric work that has hitherto been done in the British Isles is quite inadequate to give a correct representation of the physical characters of our population.

As an indication that a complete anthropometric survey will show that quite different racial types will be found inhabiting different parts of the country, I exhibit a cephalic chart of a number (not very large) of measurements I have made of persons drawn from all parts of the British Isles. The contrast, say, between Yorkshire and Cornwall and Devon is very marked. But much more numerous data would be required to establish these results.

The utilitarian applications of national anthropometry are likely to be of immense value to the social reformer. The evolution of man is determined by the actions and reactions that take place between man and his environment. The genetic environment by the process of natural selection determines the capacities of the stock; the trophic environment controls the growth and activities of the living bodies, and produces a more or less efficient population from a given stock.

It is of immense importance to know which of these modes of action of the environment exerts the greatest influence on man for good or evil. On this depends whether social legislation should be directed in the first place to the improvement of the trophic factors, such as nutrition, housing, physical training, education, &c., or to the introduction of genetic measures which would improve the stock by selection.

The collection of exact data by the measurement of the physical and mental characters of the people and the factors of their environment is the only method by which the above-mentioned problem can be solved.

By the calculus of correlation the degree of association between any given factor of a child's environment and its physical and mental characters can be determined and compared with the influence of stock on the same characters. For example, it has been shown by Miss Elderton that the stock of the parent has more influence on the physique of the child than the presence or absence of drinking habits.

Only the scantiest data exist at the present time for the solution of these vital problems, and such few and statistically imperfect examples as have been worked out appear to show that our measures of social reform are more often than not misdirected.

Apart from the changes in our environment that have been introduced by legislation within the last century, the vast social changes that have been introduced by the growth of industry require to be carefully studied and directed by periodic measurements of the population. A few of these changes may be realised from the charts in a recently published Blue Book (Cd. 4671).

Within the last fifty years the population of England has doubled, and almost as great an increase has taken place in the population of Wales

[1] See Report Brit. Assoc., 1883, p. 264.

and Scotland. The population of Ireland, on the contrary, has decreased by 33 per cent. Unless the mating, fertility, death-rate, and gains and losses by migration of the population have been very nicely adjusted a considerable change in the physique of the people may be expected from these great changes in the number and distribution of the population.

Another great change that has taken place within the last fifty years is the great increase in the proportion of the urban population as compared with the rural population. Fifty years ago only one-half the population lived in towns; to-day 77 per cent. of the population do so. Now, this does not mean, as has often been supposed, that the country has been depopulated, for it will be seen by the diagram exhibited that the rural population is only four to five per cent. less than it was fifty years ago, *i.e.*, it has remained practically constant, while the whole increase of the population has accumulated in the towns.

The conditions of life in town and in country are vastly different, and the relative rate of increase of different classes may be expected to be very different. Is this great change making for the improvement or the deterioration of the people? That is a question which can only be settled by periodic national anthropometry.

From the same Blue Book I exhibit a map showing the distribution of pauperism in England. Is this peculiar distribution due to race, or to the special conditions of the districts in which the people live?

The maximum pauperism appears to correspond very closely with the area occupied by the southern Saxons, the Jutes of Kent and the Angles of North England being free from the taint. This would suggest that pauperism was more affected by stock than by trophic environment, which cannot, as far as one can guess, be very different in these districts from that in the rest of England. If more exact observations were to prove that it was indeed associated with the Saxon race, then we should have to come to the conclusion that the race which, by its spirit of adventure and fine military qualities, once conquered England has now succumbed in the struggle for existence when the environment has been changed from the military to the industrial.

This is another question that can only be settled by national anthropometry.

National anthropometry will never be adequately carried out until it is established as a State institution. The Government have been asked to undertake this important work, which has been recommended as of primary importance by the Interdepartmental Committee on Physical Deterioration. They have taken one step in the right direction by directing the annual measurement of the weight and stature of the children in primary schools. But this is not enough to give a sufficient estimate of the physique of the nation. Japan, Denmark, and Germany have shown more alacrity than our own Government in adopting the suggestions of British scientists.

No measurements of adults are made by the State, and this in the meantime must be carried out, as far as possible, by private enterprise.

The Corresponding Societies of the British Association appear to be specially fitted to take up, to some extent, the work neglected by the State.

Each society might form an Anthropometric Committee, which would organise the work in its own district.

Complete instructions for carrying out anthropometric work have been drawn up by the Anthropometric Committee of the British Association, and will be found in the Report published by the Royal Anthropological Institute at the price of one shilling.

Local societies have done good work in the past by their observations on local botany, geology, zoology, &c. Why should they not perform equally good work in local anthropometry? This science is not more difficult to master than the other natural sciences in which they have already achieved

so much; it is equally if not more interesting, and the results obtained would be of the greatest utility in promoting the higher efficiency of the nation and maintaining our position in the front rank of the great nations.

[A demonstration of methods of measurement was then given.]

In the subsequent discussion Mr. A. L. Lewis (Royal Anthropological Institute) remarked, in reference to Mr. Gray's pauperism map, that the type of Poor Law Guardian in the respective localities might perhaps be usefully investigated as an assistance to the solution of the problem. The following members of the Conference also spoke:—Colonel Underwood, the Rev. R. Ashington Bullen, and Messrs. F. Balfour Browne, W. Whitaker, Mark L. Sykes, and W. P. D. Stebbing.

Second Meeting, October 26.

The meeting was presided over by Dr. A. C. Haddon (Chairman).

Thanks were passed to Mr. Gray for attending, before the business of the day commenced, with his measuring instruments and demonstrating their use.

The Chairman read a motion relating to the work of the British Association and its corresponding societies, brought forward by Mr. H. D. Acland, but the subject, after discussion, was withdrawn.

Professor R. Meldola introduced the discussion on the 'Suggested Publication Fund' circular of the Corresponding Societies Committee. This points out that—

'There is reason for believing that many, if not most, of the scientific societies in this country are suffering from want of sufficient means to enable them to publish the results of original investigations which are presented by their fellows or members. The scientific activity of the country, as represented by the publications of these societies, is steadily increasing; but with this increased output of scientific work there has not been a corresponding increase in the finances of the societies concerned, and so in many cases their resources are strained to such an extent that their Councils are unable to publish much of the original work done, or, if they spend to the utmost extent of their resources upon their publications, their work in other directions is crippled.

'This state of affairs has recently been discussed by our Committee, and it is considered that the time is opportune for getting an expression of opinion from all our scientific societies, with a view to deciding, if thought desirable, upon some line of action. As assistance is required towards the cost of publishing, it has been suggested that the establishment of a Publication Fund of the same kind as the Government Grant for Scientific Investigations, now administered by the Royal Society, would be the best method of dealing with the difficulty. How such a fund could be obtained, and whether the assistance of the Government should be asked for, are questions which could be considered after the general principle of the necessity of obtaining some such means of promoting work, which is really of national importance, has been decided upon.'

The circular goes on to specify the form of the present direct State aid for the promotion of scientific research. It considers the necessity for a body of evidence on the state of affairs and the means available by scientific societies for publication. Continuing, it suggests that the societies receiving the circular can show 'Whether it is desirable that any concerted action should be taken with a view to relieving scientific societies of a portion of the burden of publishing the results of original investigations' and whether 'the increase of the Government grant by an amount to be earmarked for this particular purpose would be the most effective means of rendering such assistance.' The Committee point out that to carry weight in any action

that may be taken it is important that facts and figures should be cited by each Society in addition to its general views.

The circular is signed by the President and General Officers of the Association and ten members of the Committee.

Mr. John Hopkinson (Hertfordshire Natural History Society and Field Club) introduced the following subject:—

The Financial Position of our Local Societies.

A few days ago I examined the most recent balance-sheets of a dozen of our affiliated societies, taking only those which I knew to be doing good local work. A bare majority appeared to be in a sound financial position, but the rest were not so. Two had transferred funds from their life-membership account to provide for their ordinary expenditure, one of these transferring £10 and leaving a balance of £5 due to the Treasurer. One had spent £10 more than its income and had a balance of £10, so that with another similar year its funds would be exhausted. One had an adverse balance of £52, and the report stated that the work of its museum was much crippled for want of adequate funds; its expenditure included interest on bank overdraft. The fifth showed a deficiency of £73. Thus five out of the twelve appeared to be in a critical position from want of funds. The figures given are approximate only.

I will now give a little information about the Society which I represent and its financial position.

When, on removing from London to Watford in 1874, I suggested the formation of a Natural History Society and asked a geological friend to be Treasurer, he hesitated to consent because, he said, his office would be a sinecure, for there were not half-a-dozen scientific people in Watford. The Society was founded in January 1875, and numbered 150 in its first year, including five honorary and five life members. The membership extending over the county, the title of the Society was changed, in 1879, from the Watford to the Hertfordshire Natural History Society, and in its palmiest days numbered 288 members of all classes and possessed over £350, mostly invested.

About that time a botanical member, A. R. Pryor, died and bequeathed to the Society his botanical library, herbarium, MSS., and £100 (reduced to £92 by legacy duty) for the upkeep of the library. His MSS. chiefly consisted of a Flora of Hertfordshire, which the Society published at a loss of £205 on the subscription list for it, and since its publication the sale has realised on the average scarcely one-half per cent. per annum of that loss.

Owing to loss of members from lack of interest in East Herts, to deaths and the removal of members from the county, chiefly from Watford, and to the few new members who can be obtained, the income of the Society is now greatly reduced, only £100 is invested, being half the amount of the composition fees of forty existing life-members, and there has lately more than once been an adverse balance at the end of the year.

When the Society was founded scarcely anything was known of the natural history of Hertfordshire, using this term in its widest sense, except the geology, and to that the members have added much information in the Transactions. The meteorology of the county has been very thoroughly investigated. For twenty years the monthly results of observations at four Climatological Stations have been published annually (for twelve of these years at five stations), and for the whole period of thirty-four years tables of the monthly rainfall at numerous stations, now numbering over fifty. Owing to the large amount of tabular matter these meteorological reports are expensive to print. The information they give has proved of great practical value in questions relating to water-supply. In addition to the publication of Mr. Pryor's Flora, much botanical information has been given, chiefly relating to cryptogamic plants. In almost all departments of zoology much

good work has been done, and it may be said that practically all the knowledge we possess of the zoology of the county is due to the existence of the Society. The prehistoric archæology and the topography of the county have also received much attention, the most complete list extant of the maps of any English county being that of Hertfordshire published by the Society. It runs to 164 pages, has maps and other illustrations, and cost £62, the author providing the blocks for the illustrations and contributing towards the expense of printing the last of the four parts of which it consists. Of other important papers may be mentioned one of thirty-two pages on Hertfordshire earthquakes and a list of Hertfordshire Diptera of twenty-eight pages.

The Transactions have from the first been almost entirely devoted to the publication of the results of local scientific investigations. Fifteen volumes, comprising 4,900 pages with ninety-one plates and numerous text-figures, have been published at a cost of £1,700, and a new volume has been commenced, but owing to want of funds we are a year behindhand, having only just printed the papers read during the session 1907-8.

The Society has accumulated, chiefly by exchanges and the Pryor bequest, a valuable scientific library, but from want of funds for its proper accommodation it is stored in an almost inaccessible room lent gratuitously by the Watford Urban District Council, and the subscription to several scientific journals has had to be discontinued.

The formation of a museum was commenced, and the collections formed the nucleus of the Hertfordshire County Museum at St. Albans, which the Society was almost solely instrumental in founding. The museum is free, and has, on the average, from 150 to 200 visitors per week. It has been made, by a member of the Society, a Climatological Station, and a Daily Weather Chart is shown at the gates and is much consulted.

The Society presented a petition to the Hertfordshire County Council which resulted in an order being issued protecting our rarer and beneficial birds, the schedule being drawn up by its ornithological members. It organised two public meetings, which resulted in Bricket Wood Common being preserved as common land in its natural state; and lately it assisted the Watford Field-path Association, an offshoot of the Society founded by its members, in calling a public meeting which was greatly instrumental in fifty acres of Cassiobury Park, which had been sold for building-land, being secured as a public park for Watford, and entirely so in securing that this park is open to the remaining portion of Cassiobury Park instead of being surrounded by houses.

Great economy is exercised in carrying on the Society. There is one paid assistant whose salary has recently been reduced from £5 to £3 per annum. Authors now have to pay the cost of providing illustrations for their papers, and instead of being presented with twenty-five reprints, twenty copies of the Transactions are cut up for their use.

Although the membership has been much reduced during the last twenty, and especially during the last ten years, the number of its working naturalists and the interest taken by them in its proceedings has increased, and more and also better local work has lately been done by them. Much, however, remains to be accomplished, especially in the investigation of the lower and minuter forms of life, and the value of the annual reports by the various Recorders increases as they extend over a greater length of time. This is especially the case with meteorological and phenological observations, and it would be a matter of great regret if the tables of monthly rainfall could no longer be published, or even if there were a break in their continuity. It is towards the expense of such costly contributions as these, and of such important works as the late Mr. Pryor's Flora of Hertfordshire and Sir George Fordham's Catalogue of Hertfordshire Maps, that a contribution from an outside source would be most welcome.

It may be asked, Why not economise by printing less? The answer is that nothing, except an occasional Presidential Address, is printed but the results of local investigation or what is helpful in such investigation and may encourage it; and there is no other local medium for the publication of such matter; and also that many of the members live at too great a distance from the places where meetings are held to attend them, and therefore can only be retained on our list by giving them something worth having in the Transactions in return for their subscriptions.

A joint discussion then took place on the two subjects.

Sir Alexander Pedler (British Science Guild), in reply to an invitation from the Chair, said he could only give the meeting information on the subject of the deputation of the British Science Guild, about eighteen months ago, to the Postmaster-General, with a view of obtaining a reduction in the rate of postage on the publications of scientific and learned societies. In that connection about 110 important societies were approached, and almost all were strongly in favour of the proposal as giving much-needed relief, and they joined in the arrangements which culminated in the deputation. It was considered most anomalous, and indeed unfair, that while printed matter, consisting largely of advertisements, on which a profit was made, and which are absolutely of no permanent value, could, if only registered as a newspaper, be sent by newspaper-post, under which a weight of five pounds cost only a halfpenny; on the other hand scientific publications, such as those issued by the Royal, Chemical, Physical, and other societies, which are of the utmost value to the progress of the nation, and which are produced at great cost and not for profit, could only be sent by post at a cost which is usually six or eight times as great as that of a newspaper, which is published in order to make a profit for an individual. However, the Postmaster-General could not see his way to grant the desired relief; but his reply was very sympathetic, and he showed himself to be distinctly in favour of some aid being given by Government to help scientific societies to carry on their valuable work. The British Science Guild did not, however, consider that this reply finally disposed of the postal question, and there was an intention to raise the subject at some future date, when circumstances are more favourable.

Dr. Alexander Scott (Chemical Society), who submitted a detailed table of the expenditure of his society on publications from 1900 to 1908 inclusive, drew attention to the continually increasing cost of this branch of their work. A considerable sum in the balance-sheet was incurred through their custom of handing over to some of their younger fellows literature on chemical subjects, the matter of which was abstracted for publication and paid for at a low rate.

The Chairman, Dr. A. C. Haddon (Royal Anthropological Institute), who spoke on certain aspects of the subject as it affected his society, was followed by

Mr. A. L. Lewis, who added that the Royal Anthropological Institute publishes a very large and handsome *Journal* in half-yearly parts, at 15*s*. each, free to the fellows, whose subscription is two guineas per annum. It also publishes *Man* at one shilling monthly, but it is not able to supply this free to the fellows, for want of funds. The postage on these publications is, of course, a large item. The Institute occasionally receives reports and papers for publication in its *Journal* from the Foreign and Colonial Offices, and is very glad to do so, because they are often extremely valuable; but it would also be glad to receive—what at present it does not—a grant to pay for the printing of them. The financial position of the Institute is, however, better now than it was a few years ago.

Mr. E. B. Knobel (Royal Astronomical Society) gave details of his

society's expenditure on their publications and the amount per cent. of their income. He deplored the present-day want of conciseness. With regard to the easing of the burden of postage, the deputation to the Postmaster-General showed insuperable difficulties to be surmounted in discriminating between societies. His society was a rich one and in a different position from local societies, but he would like to have more statistics. He bore testimony to the loyalty of the amateurs of science and the valuable unpaid work that was done.

Dr. Chalmers Mitchell (Zoological Society) pointed out that the administration of any Government fund for aiding scientific publication would involve a very severe scrutiny of the quality of papers read at the meetings of local societies. Many such papers would lose their local utility if they were reduced merely to the new matter they might contain, whilst the difficulties of local societies would be increased if it were known that the publication of memoirs could take place only after a rigid censorship. On the other hand he expressed his opinion that there was no difficulty in getting good new work published by the local societies, and that it was of great importance that the number of publications in which new contributions to science were published should be diminished rather than increased. In zoology alone there were already over 1,200 publications in which such new work might appear, and even the combined London libraries did not contain all of these. He opposed the establishment of the suggested fund.

The Rev. T. R. R. Stebbing said he rather expected to be in the invidious position of a single dissentient. But the last two speeches encouraged him to hope that his own point of view has its fair share of supporters. Indirectly, indeed, it derived assistance from an unexpected quarter last Sunday morning in Westminster Abbey, when the Bishop of Colchester was pleading for the thousands of clergy with inadequate incomes. He mentioned many futile expedients suggested for increasing those incomes. One was that the clergy should write. The objection to that was, he said, that a great many of them cannot write—meaning, of course, that they cannot write anything of saleable, money-getting value. But further, he said, as a rule we don't want them to write; we want only those to write who have a true gift for it. The very same rule applies to scientific writing. Again, yesterday morning our Chairman in his address alluded to some out of the way subject, something like pithecanthropogeography, and explained that when he was taking it up he immediately found that *innumerable* books had been written upon it. The fact is that however obscure, however minute the branch of science on which a student enters may be, he presently finds that it has been handled in a vast variety of widely distributed treatises which it is more or less difficult to get hold of. Dr. Chalmers Mitchell has just been insisting on this. Now the library of the Zoological Society is perhaps the best in the world for zoology, the most accessible, the most friendly; and yet the Secretary confesses to this difficulty, and however readily the library offers its resources workers in the North of England may not find it easy to use them. Why should we go about to increase the complexity of scientific literature? The present proposal, at least as originally explained to him, must have that effect. It is a proposal which he had strenuously opposed before it was made, at any rate before it received its present embodiment. When you send round to all the scientific societies in the kingdom, inviting them to uphold an appeal to Government for financial assistance, naturally in upholding such an appeal many of them will expect to share in the spoil. Probably there will not be such societies as the famous Royal Polytechnic of Cornwall, the premier, he believed, among local scientific institutions, but others of quite different quality, however meritorious in their way. Accordingly the grant runs the risk of being used, in part at least, for bolstering up 'pauper' scientific societies, helping lame dogs over stiles into fields where lame dogs are not wanted,

increasing the output of a literature which is already overwhelming, and multiplying centres of publication when every effort is desirable for their greater concentration.

Mr. J. A. Longden (Institution of Mining Engineers) said the matter appeared to him to be a question of pounds, shillings, and pence, and he knew their late Secretary had been very anxious that the Postmaster-General should put scientific postage on the same rate per pound as any other printed matter. The Institution he represented had 3,000 members, and the contribution was two guineas per annum, and to meet deficiency the subscription had recently been raised. Any saving effected by this method would undoubtedly assist in the publication of good papers. As to the suggestion that a Government grant should be obtained, Professor Milne told him that a few years ago the Government granted 100*l.* per annum towards the cost of his wonderful records in the Isle of Wight, and a Board of Trade official went to see him, and told him what the requirements of the Board of Trade would be in consideration of the grant named. The Professor said he begged to decline the grant, and thought he knew best how to carry on his work. The speaker thought this 100*l.* per annum now went to Germany. The difficulty is that the Postmaster-General will not be willing to reduce his receipts voluntarily, and on the other hand the Government will not make grants without attaching conditions. He suggested that the Postmaster-General be pressed in common fairness to accede to this request.

Mr. Balfour Browne suggested that the spirit of Socialism was invading the scientific societies since it was proposed to ask for State aid for the publication of their papers. He was entirely opposed to this step, and considered it unnecessary. The local societies publish a good many papers which are quite outside their scope; for instance, the Norfolk and Norwich Naturalists' Society published a few years ago papers on the 'Butterflies of Switzerland,' and there are numerous similar examples. These societies could save expenses on this sort of paper. So long as there is sufficient energy in a district to keep a society going that society will not go bankrupt, and it is most advisable that if the interest wanes the society should be allowed to die, and should not be kept alive by outside aid. A good paper can always find a publisher, and the cure for the present state of poverty of some of the societies is the cutting out of papers which have nothing to do with the work of the local society.

Mr. Whitaker said that the discussion under the last speakers seemed to him to have largely gone off the point. The Committee, in their proposal, had certainly no idea of subsidising presidential addresses. What was wanted was help for only important papers, and although the Government grant to the Royal Society was available to outside societies it was so small that it had to be largely used for publishing the research-papers of the Royal Society itself.

Mr. H. D. Acland (Royal Institution of Cornwall) thought that it appeared to have been forgotten that there are two classes of scientific societies, large central and small local ones. Small local ones should be self-supporting. Papers worthy of publication could be read before large societies, if accepted by them. Societies should be very chary of accepting grants from the State, as it would involve State control. Papers worth publishing by State aid should be State Papers.

Mr. William Watts (Geological and Mining Institution of Manchester) said the publication fund under discussion had been considered by his Council, who saw difficulties in obtaining a grant from the Government in carrying on the work of the society, but would be glad if some concessions could be made to them in reducing the cost of transmitting the society's proceedings through the Post Office. His society was not directly in want of funds, as the members' subscriptions maintained them, but an easement in

the cost of postage would enable the proceedings of the society to become more widely known.

Mr. J. Howard Reed (Manchester Geographical Society) said that he was not in favour of a fund for publishing original work, but was for some arrangement that would ease scientific societies of the burden of postage.

Colonel Underwood (Ipswich and District Field Club) said: Several delegates have deprecated any grant being asked for from the Government, but these gentlemen represent rich societies with comparatively large incomes and a high entrance fee. The society I represent has a low entrance fee (2*s.* 6*d.*), but I venture to think we are doing a good work, and we are publishing a journal entirely composed of original research. In accordance with the views of our Chairman, which he has set forth in his excellent address on "Regional Surveys," we have grouped our field club into sections, each under a leader, which are carrying on original research in several subjects, notably in marine biology at Felixstowe by means of sea-dredging and microscopic investigation. It seems to me that the difficulty which some of the speakers pointed out of the danger of encouraging by Government assistance the publication of journals of no use to science might be avoided by allocating the grant to some society, such as the British Association, who could appoint a committee to decide from a perusal of the journals which societies were worthy of participating in the grant. If science in this country is to be decentralised and made more generally popular, it can only be done by judiciously assisting those societies which are full of zeal and doing a good educational work, but are in want of the necessary funds to extend their operations. Our members are largely composed of school-teachers whose means are small, but who, as the leaders of the young, should be encouraged in every way.

Mr. A. B. Harding (Catford and District N. H. Society), speaking as the representative of a small local association, said that they had a membership of seventy-five, each paying an annual subscription of 3*s.*; new members also paying an entrance fee of 1*s.* Unlike many societies represented here to-day they had no adverse balance, never having been in a position to open a banking account. So far from being able to publish papers read, we can only afford to issue notices of forthcoming meetings. Yet much of the work done by members is original and of high value, *e.g.*, memoirs of long-continued observations on British alien plants, the effect of controlled diet on Lepidoptera, and many geological and archæological points of importance, the publication of which could hardly fail to prove helpful to science. Personally they seek no recompense; all they suggest is that papers of special merit, selected by the Committee, should be submitted to the Council of the British Association, and whenever their judgment is in favour of publication a grant towards this object should be made out of any funds obtained for such a purpose from the Treasury.

Dr. G. B. Longstaff (Entomological Society of London) said that the society which he represented occupied itself not only with the necessary systematic work, but had of late years been greatly concerned with bionomic problems. For the solution of the latter it was essential that naturalists should publish their observations, and not take their knowledge with them to the grave. In the study of the working of natural selection it was of great importance to have numerous exact and repeated observations of, *e.g.*, the attacks of birds on butterflies. Mr. G. A. K. Marshall had got together a mass of evidence, but much more was required. Sportsmen (in many cases half naturalists) might collect such information, so might gardeners. Tropical collectors had several times of late complained that they did not know what observations were required. They did not know what to look for, and if interesting facts came to their notice often failed to record them. He proposed the following resolution:

'That this meeting hopes that the British Science Guild will persist in its efforts to induce the Post Office to give scientific societies the same postal facilities as the publishers of newspapers and traders in general.' This was seconded by the Rev. T. R. R. Stebbing.

The discussion was continued by Mr. Mark L. Sykes (Manchester Microscopical Society), who put forward a proposal that was not seconded; the Rev. J. O. Bevan, who approved of the principle of Dr. Longstaff's motion; Mr. W. A. Nicholson (Norfolk and Norwich Naturalists' Society), who as a member of a body numbering 270 members, with small funds, was in favour of the Publication Fund; and Professor R. Meldola, who said that he would be pleased to co-operate at some future date in Dr. Longstaff's proposal, but that the present time was hardly suitable to re-introduce the subject.

Sir Alexander Pedler said that a reconsideration of this matter by the British Science Guild was at present in abeyance. Dr. Longstaff's proposal was then passed by the meeting on the understanding that it would be considered by the Corresponding Societies Committee.

The Rev. J. O. Bevan submitted the following proposal to the delegates: 'That this Conference expresses its opinion that the Government be asked to enlarge the grant already allocated to the Royal Society.' Professor R. Meldola criticised the proposal, as it presupposed the willingness of the Royal Society to administer such an enlarged grant. Mr. R. A. Bellamy (Ashmolean N. H. Society of Oxfordshire) having spoken in favour of the Publication Fund, Professor Meldola moved the following amendment: 'That, in view of the opinions elicited during this Conference, the question of the advisability of taking further action be referred for consideration by the Corresponding Societies Committee.' This was seconded by Mr. Whitaker, and carried.

The meeting then adjourned, after passing a hearty vote of thanks to the Chairman for presiding.

The Corresponding Societies of the British Association for 1909–1910.

Affiliated Societies.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Andersonian Naturalists' Society, 1885	Technical College, Glasgow. R. Barnett Johnstone and George Lunam	308	None	2*s.* 6*d.*	Annals, occasionally.
Ashmolean Natural History Society of Oxfordshire, 1828	Miss A. L. Stone, 2 St. Margaret's Road, Oxford	320	None	5*s.*	Report, annually.
Bath Natural History and Antiquarian Field Club, 1855	J. Langfield Ward, Royal Literary and Scientific Institution, Bath	50	5*s.*	10*s.*	Proceedings, annually.
Belfast Natural History and Philosophical Society, 1821	Museum, College Square. R. M. Young, M.R.I.A.	250	None	1*l.* 1*s.*	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	Museum, College Square. A. W. Stelfox and Miss Jean Agnew	402	5*s.*	5*s.*	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Rev. J. J. M. L. Aiken, B.D., Manse of Ayton, Berwickshire	400	10*s.*	8*s.* 6*d.*	History of the Berwickshire Naturalists' Club, annually.
Birmingham and Midland Institute Scientific Society, 1859	Alfred Cresswell, Birmingham and Midland Institute, Paradise Street, Birmingham	137	None	10*s.* 6*d.* and 5*s.*	Records of Meteorological Observations, annually.
Birmingham Natural History and Philosophical Society, 1858	Avebury House, Newhall Street, Birmingham. F. J. Brown and Herbert Stone, F.L.S.	210	None	1*l.* 1*s.*	Proceedings, occasionally.
Brighton and Hove Natural History and Philosophical Society, 1854	J. Colbatch Clark, 9 Marlborough Place, Brighton	168	None	10*s.*	Report, annually.
Bristol Naturalists' Society, 1862	J. H. Priestley, B.Sc., University College, Bristol	143	5*s.*	10*s.* and 5*s.*	Proceedings, annually.
British Mycological Society, 1896	Carleton Rea, 34 Foregate Street, Worcester	90	None	10*s.*	Transactions, annually.
Buchan Field Club, 1887	J. F. Tocher, B.Sc., 5 Chapel Street, Peterhead	180	5*s.*	5*s.*	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	H. Lloyd Hind, B.Sc., Ravenscliff, Stapenhill, Burton-on-Trent	200	None	5*s.*	Report, annually; Transactions, occasionally.
Canada Royal Astronomical Society of, 1884	Canadian Institute Building, Toronto. J. R. Collins	500	None	2 dollars	Journal, bi-monthly.
Caradoc and Severn Valley Field Club, 1893	H. E. Forrest, 37 Castle Street, Shrewsbury	207	5*s.*	5*s.*	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	W. Gilbert Scott, 25 Duke Street, Cardiff	450	None	12*s.* 6*d.*	Transactions, annually.
Chester Society of Natural Science, Literature, and Art, 1871	Grosvenor Museum, Chester. F. Simpson	1,040	None	5*s.* and 2*s.* 6*d.*	Report and Proceedings, annually.
Cornwall, Royal Geological Society of, 1814	The Museum, Public Buildings, Penzance. John B. Cornish	98	None	1*l.* 1*s.*	Transactions, annually.
Cornwall, Royal Institution of, 1818	George Penrose, F.L.S., County Museum, Truro	182	None	1*l.* 1*s.*	Journal, annually.
Cornwall Royal Polytechnic Society, 1833	E. W. Newton, Camborne, Cornwall	380	None	10*s.* upwards	Report, annually.
Croydon Natural History and Scientific Society, 1870	Public Hall, Croydon. G. W. Moore	147	None	10*s.*, 5*s.*, and 2*s.* 6*d.*	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Rev. Herbert Pentin, M.A., M.R.A.S., Milton Abbey Vicarage, Dorset	400	10*s.*	10*s.*	Proceedings, annually.
Dublin Naturalists' Field Club, 1885	J. Bayley Butler, M.A., University College, Dublin, and J. Stafford Johnson	132	Memb. 5*s.*; Assoc. none	Members 5*s.*; Associates 2*s.* 6*d.*	'Irish Naturalist,' monthly; Report, annually.

Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	S. Arnott, Sunnymead, Dumfries	265	None	5*s.*	Transactions and Proceedings, annually
East Kent Scientific and Natural History Society, 1857	A. Lander, The Medical Hall, Canterbury	81	None	10*s.* and 5*s.*	Transactions, annually.
Eastbourne Natural History, Scientific, and Literary Society, 1867	Henry Sparks, Villa Ruhe, 5 St. Leonard's Road, Eastbourne	72	2*s.* 6*d.*	7*s.* 6*d.*	Transactions, biennially.
Edinburgh Field Naturalists' and Microscopical Society, 1869	John Thomson, 21 St. Ninian's Terrace, Edinburgh	208	5*s.*	5*s.*	Transactions, annually.
Edinburgh Geological Society, 1834	India Buildings, Edinburgh. David Gloag	225	10*s.* 6*d.*	12*s.* 6*d.*	Transactions, annually.
Elgin and Morayshire Literary and Scientific Association, 1836	Norris Mackay, W.S., Elgin	196	None	5*s.*	Transactions, occasionally.
Essex Field Club, 1880	William Cole, Springfield, Epping New Road, Buckhurst Hill, Essex	300	None	15*s.*	'Essex Naturalist,' quarterly; 'Year-book,' annually; 'Special Memoirs,' &c., occasionally.
Glasgow, Geological Society of, 1858	Peter Macnair, F.R.S.E., 207 Bath Street, Glasgow	300	None	10*s.*	Transactions and Proceedings, annually.
Glasgow, Natural History Society of, 1851	Alex. Ross, 409 Great Western Road, Glasgow	265	None	7*s.* 6*d.*	Transactions and Proceedings, annually.
Glasgow, Royal Philosophical Society of, 1802	Prof. Peter Bennett, 207 Bath Street, Glasgow	1,000	1*l.* 1*s.*	1*l.* 1*s.*	Proceedings, annually.
Halifax Scientific Society, 1874	F. Barker, 11 Hall Street, Halifax	132	None	2*s.* 6*d.*	——
Hampshire Field Club and Archæological Society, 1885	W. Dale, F.S.A., F.G.S., The Lawn, Archer's Road, Southampton	250	5*s.*	10*s.* 6*d.*	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	Charles Oldham, F.Z.S., Essex House, and A. E. Gibbs, F.L.S., St. Albans	155	10*s.*	10*s.*	Transactions, twice a year.
Holmesdale Natural History Club, 1857	Miss M. C. Crosfield, Undercroft, Reigate	87	None	10*s.* and 5*s.*	Proceedings, occasionally.
Hull Geological Society, 1887	J. W. Stather, F.G.S., Newland Park, Hull	68	None	5*s.*	Transactions, occasionally.
Hull Scientific and Field Naturalists' Club, 1886	T. Stainforth, The Museum, Hull	138	None	5*s.*	Transactions, annually.
Institution of Mining Engineers, 1889	Percy Strzelecki, 39 Victoria Street, S.W.	3,350	None	None	Transactions, monthly.
Ireland, Statistical and Social Inquiry Society of, 1847	W. Lawson, Dr. N. M. Falkiner, and Herbert Wood, 35 Molesworth Street, Dublin	100	None	1*l.*	Journal, annually.
Leeds Geological Association, 1873	E. Hawkesworth, Crossgates, Leeds	118	None	5*s.*	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Corporation Museum. W. A. Evans, 24 Fosse Road South, Leicester	350 Membs. & Associates	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Transactions, half-yearly.
Lincolnshire Naturalists' Union, 1893	A. Smith, City and County Museum, Lincoln	110	None	5*s.*	Transactions, annually.
Liverpool Biological Society, 1886	J. A. Clubb, M.Sc., Free Public Museum, Liverpool	95	10*s.* 6*d.* and 2*s.* 6*d.*	1*l.* 1*s.* and 10*s.* 6*d.*	Proceedings and Transactions, annually.
Liverpool Botanical Society, 1906	A. A. Dallman, F.C.S., Lyndhurst, Prospect Vale, Liverpool	201	None	5*s.*	Proceedings, annually.
Liverpool Engineering Society, 1875	T. R. Wilton, B.A., Royal Institution, Liverpool	550	None	1*l.* 1*s.* and 10*s.* 6*d.*	Transactions and Report, annually.
Liverpool Geographical Society, 1891	Capt. E. C. Dubois Phillips, R.N., 14 Hargreave's Buildings, Liverpool	590	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Transactions and Report, annually.
Liverpool Geological Society, 1858	Royal Institution. W. A. Whitehead, B.Sc.	70	None	1*l.* 1*s.* and 10*s.* 6*d.*	Proceedings, annually.
London: Quekett Microscopical Club, 1865	W. B. Stokes, 4 Winn Road, Lee, S.E.	446	None	10*s.*	Journal, half-yearly.
London: Selborne Society, 1885	20 Hanover Square, W. W. M. Webb, F.L.S.	2,020	None	5*s.*	'Selborne Magazine,' monthly.
Man, Isle of, Natural History and Antiquarian Society, 1879	P. M. C. Kermode, Claghbane, Ramsey, Isle of Man	150	2*s.* 6*d.*	7*s.* 6*d.* and 5*s.*	Proceedings, twice a year; Transactions, occasionally.
Manchester Geographical Society, 1884	J. Howard Reed, 16 St. Mary's Parsonage, Manchester	660	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Journal, quarterly.

Affiliated Societies—continued.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Manchester Geological and Mining Society, 1838	5 John Dalton Street, Manchester. Sydney A. Smith	300	None	2*l.* 2*s.*, 1*l.* 5*s.*, 1*l.* 1*s.*, and 1*l.*	Transactions of Inst. of Mining Engineers, monthly.
Manchester Microscopical Society, 1880	Frederick Dishley, 14 Westwood Street, Moss Side, Manchester	217	5*s.*	6*s.*	Transactions and Report, annually.
Manchester Statistical Society, 1833	Theodore Gregory, 3 York Street, Manchester	180	10*s.* 6*d.*	10*s.* 6*d.*	Transactions, annually.
Marlborough College Natural History Society, 1864	E. Meyrick, F.R.S., Marlborough College	280	1*s.* 6*d.*	3*s.* and 5*s.*	Report, annually.
Midland Counties Institution of Engineers, 1871	G. Alfred Lewis, M.A., Albert Street, Derby	120 Membs., Associates & Students	1*l.* 1*s.* None	Members 42*s.*; Associates and Students 20*s.*	Transactions of Institution of Mining Engineers, monthly.
Midland Institute of Mining, Civil, and Mechanical Engineers, 1869	L. T. O'Shea, The University, Sheffield	306	None	1*l.* 10*s.*	Transactions of Inst. of Mining Engineers, monthly.
Norfolk and Norwich Naturalists' Society, 1869	W. A. Nicholson, 51 Surrey Street, Norwich	284	None	6*s.*	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	Neville Hall, Newcastle-upon-Tyne	1,350	None	25*s.* and 42*s.*	Transactions of Inst. of Mining Engineers, monthly.
North Staffordshire Field Club, 1865	W. Wells Bladen, Stone, Staffs	570	5*s.*	5*s.*	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	H. N. Dixon, M.A., 17 St. Matthew's Parade, Northampton	210	None	10*s.*	Journal, quarterly.
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of, 1829	Hancock Museum, Newcastle-on-Tyne. N. H. Martin, F.L.S., and C. E. Robson	430	None	21*s.*	Transactions, annually.
Nottingham Naturalists' Society, 1852	Prof. J. W. Carr, M.A., University College, Nottingham	207	2*s.* 6*d.*	5*s.*	Report and Transactions, annually.
Paisley Philosophical Institution, 1808	J. Gardner, 3 County Place, Paisley	572	5*s.*	7*s.* 6*d.*	Report and Meteorological Observations, annually.
Perthshire Society of Natural Science, 1867	Tay Street, Perth. S. T. Ellison	382	2*s.* 6*d.*	5*s.* 6*d.*	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	J. Reginald Ashworth, D.Sc., 105 Freehold Street, Rochdale	244	None	6*s.*	Transactions, biennially.
Rochester Naturalists' Club, 1878	John Hepworth, Linden House, Rochester	175	None	5*s.*	'Rochester Naturalist,' quarterly.
Somersetshire Archæological and Natural History Society, 1849	The Castle, Taunton. Rev. F. W. Weaver, Rev. E. H. Bates, and C. Tite	771	10*s.* 6*d.*	10*s.* 6*d.*	Proceedings, annually.
South African Philosophical Society, 1877	G. M. Clark, South African Museum, Cape Town	207	None	2*l.*	Transactions, occasionally.
South-Eastern Union of Scientific Societies, 1896	Rev. R. Ashington Bullen, B.A., Englemoor, Heathside Road, Woking	56 Societies	None	Minimum 5*s.*	'South-Eastern Naturalist,' annually.
Southport Literary and Philosophical Society	Arthur Quayle, 2 Post Office Avenue, Southport	90	None	7*s.* 6*d.*	Proceedings, occasionally.
South Staffordshire and Warwickshire Institute of Mining Engineers, 1867	G. D. Smith, 3 Newhall Street, Birmingham	157	1*l.* 1*s.* and 10*s.* 6*d.*	31*s.* 6*d.* and 21*s.*	Transactions of Institution of Mining Engineers, monthly.

Tyneside Geographical Society, 1887	Geographical Institute, St. Mary's Place, Newcastle-on-Tyne. Herbert Shaw, B.A., F.R.G.S.	1,000	None	10s.	Journal, annually.
Vale of Derwent Naturalists' Field Club, 1887	J. E. Patterson, Mossgiel, Rowlands Gill, R.S.O.	166	None	2s. 6d.	Transactions, occasionally.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Museum, Warwick. C. West, Cross Cheaping, Coventry	70	2s. 6d.	5s.	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	234	10s.	10s.	Transactions, biennially.
Worcestershire Naturalists' Club, 1847	Education Offices, Worcester, F. T. Spackman, F.G.S.	120	10s.	5s.	Transactions, annually.
Yorkshire Geological Society, 1837	W. Lower Carter and Cosmo Johns, Burngrove, Pitsmoor Road, Sheffield	218	None	13s.	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	The Museum, Hull. T. Sheppard, F.G.S.	470 and 3,356 Associates	None	10s. 6d.	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822	Museum, York. Dr. Tempest Anderson and C. E. Elmhirst	480	None	2l.	Report, annually.

Associated Societies.

Balham and District Antiquarian and Natural History Society, 1897	A. L. Barron, Clophill, Wallington, Surrey	71	None	5s.	Papers, occasionally.
Barrow Naturalists' Field Club and Literary and Scientific Association, 1876	Cambridge Hall, Strand, Barrow. W. L. Page, 5 Cavendish Street	335	None	5s. and 2s. 6d.	Report and Proceedings, &c., annually.
Battersea Field Club, 1894	Public Library, Lavender Hill, Battersea, S.W. Miss L. B. Morris	50	None	3s. 6d.	—
Bournemouth Natural Science Society, 1903	Dr. J. R. L. Dixon, Sherbrook, Christchurch Road, Bournemouth	260	None	10s.	Report, annually.
Bradford Natural History and Microscopical Society, 1875	Fred. Jowett, Vincent Street, Bradford	98	1s.	4s.	Report, annually.
Bradford Scientific Association, 1875	Rosse Butterfield, Bank House, Wilsden, Bradford	200	None	5s. and 2s. 6d.	Bradford Scientific Journal, quarterly.
Catford and District Natural History Society, 1897	W. H. Griffin, 40 Blythe Vale, Catford, S.E.	80	1s.	3s.	—
Dover Sciences Society, 1879	Arthur W. Gilham, Holmesdale, Priory Hill, Dover	60	None	6s.	Reports, annually; Leaflets occasionally.
Dunfermline Naturalists' Society, 1902	Robert Somerville, B.Sc., 38 Cameron Street, Dunfermline	180	None	3s.	—
Ealing Scientific and Microscopical Society, 1877	F. McNeil Rushforth, Coley Lodge, 21 Florence Road, Ealing, W.	125	None	10s. and 2s. 6d.	Report and Transactions annually.
Grimsby and District Antiquarian and Naturalists' Society, 1896	The Museum, Grimsby. Dr. G. A. Grierson	102	None	4s.	—
Hampstead Scientific Society, 1899	C. O. Bartrum, B.Sc., and R. W. Wylie, M.A., 12 Heath Mansions, Heath Street, Hampstead, N.W.	273	None	Minimum 5s.	Report and Proceedings, annually.
Hastings and St. Leonards Natural History Society, 1893	Corporation Museum, Brassey Institute, Hastings. W. Ruskin Butterfield	470	1s.	2s. 6d.	'Hastings and East Sussex Naturalist,' half-yearly.

Associated Societies—continued.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Hawick Archæological Society, 1856	J. J. Vernon, 81 High Street, Hawick	250	None	2s. 6d.	Transactions, annually.
Inverness Scientific Society and Field Club, 1875	W. J. Watson, Royal Academy, Inverness	197	None	5s.	Transactions, occasionally.
Ipswich and District Field Club, 1903	P. G. H. Boswell, F.G.S., Endsleigh, Wellesley Road, Ipswich	180	None	2s. 6d.	Journal, annually.
Lancashire and Cheshire Entomological Society, 1877	Royal Institution, Liverpool. H. R. Sweeting, M.A.	140	None	5s.	Report and Proceedings, annually.
Leeds Naturalists' Club and Scientific Association, 1868	J. Digby Firth, F.L.S., 22 Burchett Place, Delph Lane, Leeds	84	None	6s.	Transactions, occasionally.
Lewisham Antiquarian Society, 1885	J. W. Brookes, Pembroke Lodge, Slaithwaite Road, Lewisham, S.E.	110	None	5s.	Transactions, occasionally.
Liverpool Microscopical Society, 1868	Royal Institution, Liverpool. R. Croston	55	10s. 6d.	10s. 6d.	Report, annually.
Liverpool Science Students' Association, 1881	Royal Institution, Liverpool. H. W. Greenwood	48	2s. 6d.	5s.	—
London: City of London Entomological and Natural History Society, 1858	The London Institution, Finsbury Circus, E.C. T. H. L. Grosvenor.	79	2s. 6d.	7s. 6d.	Transactions, annually.
London: North London Natural History Society, 1892	R. W. Robbins, Tonah, Falmouth Avenue, Hale End, Chingford	105	2s. 6d.	5s. and 2s. 6d.	Report, annually.
London: South London Entomological and Natural History Society, 1872	Hibernia Chambers, London Bridge, S.E. Stanley Edwards, F.L.S.	175	2s. 6d.	7s. 6d.	Proceedings, annually.
Maidstone and Mid-Kent Natural History Society, 1868	Maidstone Museum. A. Barton and J. W. Bridge	101	None	10s. and 5s.	Report, triennially.
Newcastle-upon-Tyne, Literary and Philosophical Society of, 1793	Newcastle-upon-Tyne. Alfred Holmes and Frederick Emley	2,800	None	1l. 1s.	—
Penzance Natural History and Antiquarian Society, 1839	Public Buildings, Penzance. J. B. Cornish	50	None	10s. 6d.	Transactions, occasionally.
Preston Scientific Society, 1893	Lecture Hall, 119A Fishergate, Preston. W. Hy. Heathcote	598	None	5s.	Papers, occasionally.
Scarborough Philosophical and Archæological Society, 1828	The Museum, Scarborough. E. Arnold Wallis	101	None	1l. and 10s.	Report, annually.
School Nature Study Union, 1903	H. E. Turner, 1 Grosvenor Park, Camberwell, S.E.	1,000	None	2s. 6d.	'School Nature Study,' four times a year.
Scottish Microscopical Society, 1888	Philosophical Institution, 4 Queen Street, Edinburgh. Dr. W. G. Aitchinson Robertson	60	None	10s. 6d.	Proceedings, annually.
Southport Society of Natural Science, 1890	George Cross, Shaftesbury Buildings, Eastbank Street, Southport	268	None	5s.	Report, annually.
Teign Naturalists' Field Club, 1858	John S. Amery, Druid, Ashburton, Devon	120	None	2s. 6d.	Report, annually.
Torquay Natural History Society, 1844	Alex. Somervail, The Museum, Torquay	196	10s. 6d.	1l. 1s.	—
Tunbridge Wells Natural History and Philosophical Society, 1884	R. R. Hutchinson, 28 Princes Street, Tunbridge Wells	154	None	10s. 6d., 5s., and 3s. 6d.	Report, annually.
Warrington Field Club, 1884	Alf. J. Jolley, 16 Arpley Street, Warrington	53	None	2s.	—
Watford Camera Club, 1902	W. J. Edmonds, 3 The Parade, Watford	50	None	10s. and 5s.	—

Catalogue of the more important Papers, especially those referring to Local Scientific Investigations, published by the Corresponding Societies during the year ending May 31, 1909.

*** This Catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

Section A.—Mathematical and Physical Science.

Albrecht, Sebastian. The Lick Observatory-Crocker Expedition to Flint Island. 'Journal Royal Astr. Soc. of Canada,' ii. 115-131. 1908.

Ashmolean Natural History Society. Meteorological Report. 'Report Ashmolean N. H. Soc.' 1908, 45-50. 1909.

Ashworth, Dr. J. R. An Analysis of the Meteorological Elements of Rochdale. 'Trans. Rochdale Lit. and Phil. Soc.' ix. 43-63. 1908.

Barr, J. Miller. A Remarkable Class of Spectroscopic Binaries. 'Journal Royal Astr. Soc. of Canada,' iii. 50-53. 1909.

Bladen, W. Wells. Meteorological Report. 'Trans. N. Staffs F. C.' xlii. 90-93. 1908.

Brighton and Hove Natural History and Philosophical Society. Meteorology of Brighton. 'Report Brighton and Hove N. H. Phil. Soc.' 1907-8, 64-65. 1908.

Bulman, H. F. Meteorological Report. 'Trans. Vale of Derwent Nat. Field Club,' i. 58-71. 1908.

Campbell-Bayard, F. Report of the Meteorological Committee, 1907. 'Trans. Croydon N. H. Sci. Soc. 1907-1908,' 185-193, and Appendices, 63 pp. 1908.

Caradoc and Severn Valley Field Club. Meteorological Notes. 'Record of Bare Facts.' No. 18, 28-41. 1909.

Claridge, J. T. W. Sir William Herschel and his Astronomical Work. 'Journal Royal Astr. Soc. of Canada,' iii. 31-40. 1909.

Clark, G. Nebulæ and Nebular Hypotheses. 'Trans. Edinburgh Field Nat. and Mic. Soc.' vi. 67-81. 1908.

Coleman, Prof. A. P. Ancient Ice Ages and their Bearing on Astronomical Theories. 'Journal Royal Astr. Soc. of Canada,' ii. 132-135. 1908.

Coles-Finch, W. A. A Phenomenal Snowstorm, April 24, 1908. 'Rochester Naturalist,' iv. 10-13. 1908.

—— The Hail and Thunderstorm of June 4, 1908. 'Rochester Naturalist,' iv. 25-27. 1908.

—— Brilliant Twilight Effects, June 30 and July 1, 1908. 'Rochester Naturalist,' iv. 60-62. 1909.

Cortie, Rev. A. L. The Sun's Corona. 'Trans. Rochdale Lit. and Sci. Soc.' ix. 37-42. 1908.

Craw, J. H. Account of Rainfall in Berwickshire—Year 1906. 'History Berwickshire Nat. Club,' xx. 114. 1908.

—— Account of Temperature at West Foulden—Year 1906. 'History Berwickshire Nat. Club,' xx. 115. 1908.

Cresswell, Alfred. Records of Meteorological Observations taken at the Observatory, Edgbaston, 1908. 'Birm. and Mid. Inst. Sci. Soc.' 26 pp. 1909.

Davis, Henry. The Application of the Hygrometer in Coal Mines. 'Trans. Inst. Min. Eng.' xxxv. 285-290. 1908.

Denison, F. Napier. Lake Undulations. 'Journal Royal Astr. Soc. of Canada,' ii. 251-254. 1908.

Denison, F. Napier. The Effect of Atmospheric Pressure upon the Earth's Surface. 'Journal Royal Astr. Soc. of Canada,' ii. 293-298. 1909.

Elvins, Andrew. High Water in Lake Ontario. 'Journal Royal Astr. Soc. of Canada,' ii. 209-210. 1908.

Espin, T. E. Notes on Double Stars. 'Journal Royal Astr. Soc. of Canada,' ii. 248-250. 1908.

—— List of Stars marked Double by Argelander, and not recorded by previous Observers. 'Journal Royal Astr. Soc. of Canada,' ii. 279-281. 1909.

—— Volcanic Phenomena considered in relation to Parallels of Latitude and Meridians of Longitude. 'Journal Royal Astr. Soc. of Canada,' iii. 107-113. 1909.

Evans, Edgar J. Note on the Severn Bore. 'Trans. Cardiff Nat. Soc.' xli. 50. 1909.

Evans, J., and G. L. V. Baker. Meteorological Observations at Oundle School. 'Journal Northants N. H. Soc.' xiv. 336. 1909.

Gilchrist, L. Spectra of Water-Vapour in the Earth's Atmosphere. 'Journal Royal Astr. Soc. of Canada,' iii. 45-49. 1909.

Gilligan, Albert. Some Effects of the Storm of June 3, 1908, on Barden Fell. 'Proc. Yorkshire Geol. Soc.' xvi. 383-390. 1909.

Gray, James G., and Alexander D. Ross. The Construction of Permanent Magnets from Specimens of nearly Pure Copper. 'Proc. Glasgow R. Phil. Soc.' xxxix. 92-96. 1908.

Hall, Henry (Manchester Geol. Min. Soc.). Ignition Points of Wood and Coal. 'Trans. Inst. Min. Eng.' xxxvi. 2-5. 1908.

Harper, W. E. The Orbit of θ Aquilæ. 'Journal Royal Astr. Soc. of Canada,' iii. 87-101. 1909.

Heywood, H. Meteorological Observations in the Society's District, 1906. 'Trans. Cardiff Nat. Soc.' xl. 1-17. 1908.

—— Meteorological Observations in the Society's District, 1907. 'Trans. Cardiff Nat. Soc.' xli. 1-18. 1909.

Illingworth, S. R. The Light Night of June 30, 1908. 'Bradford Scientific Journal,' ii. 183-185. 1908.

Imboden, Walter. A Simple Drawing and Projection Apparatus for Microscopical Low-power Objectives. 'Journal Quekett Mic. Club,' x. 353-356. 1909.

Jack, Robert, and Alexander D. Ross. Heusler's Magnetic Alloy. 'Proc. Glasgow R. Phil. Soc.' xxxix. 41-46. 1908.

Jennings, Samuel. Solar Eclipses and Ancient History 'Journal Royal Astr. Soc. of Canada,' ii. 167-184. 1908.

—— The Eclipses of Larissa and Thales. 'Journal Royal Astr. Soc. of Canada,' iii. 102-106. 1909.

King, W. F. The Cœlostat House of the Dominion Observatory. 'Journal Royal Astr. Soc. of Canada,' iii. 115-116. 1909.

Klotz, Otto. Microseisms. 'Journal Royal Astr. Soc. of Canada,' ii. 195-208. 1908.

—— The Forty-ninth Parallel. 'Journal Royal Astr. Soc. of Canada,' ii. 282-292. 1908.

—— Recent Progress in Astronomy and Allied Sciences. 'Journal Royal Astr. Soc. of Canada,' iii. 117-134. 1909.

Lander, A. Meteorological Notes for 1908. 'Trans. East Kent Sci. N. H. Soc.' viii. 14-16. 1909.

Lawson, Graham C. Meteorological Report. 'Trans. N. Staffs F. C.' xliii. 127-129. 1909.

León, Luis G. and Mrs. Solar Activity in December 1908. 'Journal Royal Astr. Soc. of Canada,' iii. 41-44. 1909.

Lines, Richard. Presidential Address. [Progress of Astronomy.] 'Rochester Naturalist,' iv. 33-41. 1909.

Machell, Thomas. Keyboard Percussion Instruments. 'Proc. Glasgow R. Phil. Soc.' xxxix. 13-20. 1908.

Markham, C. A., and R. H. Primavesi. Meteorological Report.—Observers' Notes. 'Journal Northants N. H. Soc.' 243-250, 252-292, 1908; 329-335, 1909.

Mellanby, Prof. A. L. Some Disputed Points in the Theory of the Steam Engine. 'Proc. Glasgow R. Phil. Soc.' xxxix. 143-154. 1908.

Meyrick, E. Summary and Tables of Meteorological Observations, 1908. 'Report Marlb. Coll. N. H. Soc.' No. 57, 63-82. 1909.

Monck, W. H. S. The Sun's Motion in Space. 'Journal Royal Astr. Soc. of Canada,' ii. 223-234. 1908.

—— The Eclipses of Larissa and Thales. 'Journal Royal Astr. Soc. of Canada,' ii. 299-302. 1909.

Motherwell, R. M. Comet 1908*c* (Morehouse). 'Journal Royal Astr. Soc. of Canada,' iii. 28-30. 1909.

Musson, W. Balfour. Development in the Stellar Universe (President's Address). 'Journal Royal Astr. Soc. of Canada,' iii. 5-27. 1909.

Paterson, John A. The Apex of the Sun's Way. 'Journal Royal Astr. Soc. of Canada,' ii. 136-148. 1908.

Pfenninger, Otto. Colour Photography. 'Report Brighton and Hove N. H. Phil. Soc.' 1907-8, 45-37. 1908.

Preston, Arthur W. Meteorological Notes, 1907. 'Trans. Norfolk and Norwich Nat. Soc.' viii. 587-595. 1908.

Rambaut, A. A. Meteorological Report. 'Report Ashmolean Nat. Hist. Soc.' 1908, 45-50. 1909.

Ross, Arthur (N. England Inst. Eng.). Circulation and Heat Absorption in Steam Boilers. 'Trans. Inst. Min. Eng.' xxxv. 429-439. 1908.

Royal Astronomical Society of Canada. Summary Report of the Weather in Canada. 'Journal Royal Astr. Soc. of Canada,' ii. 165-166, 220-222, 276-278, 338-340, 1909; iii. 84-86, 159-161, 1908.

Royal Institution of Cornwall. Meteorological Tables, 1907. 'Journal Royal Inst. Cornwall,' xvii. 296-302. 1908.

Simpson, T. Meteorological Notes for the years 1906 and 1907. 'Trans. Ealing Sci. Mic. Soc.' 1907-8, xi. 1908.

Soame, G. H. B. Rainfall in 1908 at the Meir, Longton, Staffordshire, and at Wall Grange, Staffordshire. 'Trans. N. Staffs F. C.' xliii. 130. 1909.

Stewart, R. M. Errors of Transit Observations. 'Journal Royal Astr. Soc. of Canada,' i. 185-194. 1908.

Stilwell, H. Returns of Rainfall, &c., in Dorset in 1907. 'Proc. Dorset N. H. A. F. C.' xxix. 143-152. 1908.

Stokes, A. H. (Mid-Counties Inst. Eng.) Hygrometric Observations in Coal Mines. 'Trans. Inst. Min. Eng.' xxxvi. 143-151. 1909.

Sutton, J. R. Earth Temperatures at Kimberley. 'Trans. S. African Phil. Soc.' xviii. 421-435. 1909.

Whitton, James. Meteorological Notes and Remarks upon the Weather during the year 1905, with its General Effects upon Vegetation. 'Trans. Glasgow N. H. Soc.' viii. 30-42. 1908.

Young, J. Three Exceptional Earthquakes recorded at Toronto, Ont., and Victoria, B.C. 'Journal Royal Astr. Soc. of Canada,' iii. 71-72. 1909.

Section B.—Chemistry.

Ashworth, James (N. Staff. Inst. Eng.). Notes on Recent Demonstrations of Coal-dust Phenomena. 'Trans. Inst. Min. Eng.' xxxvi. 366-371. 1909.

Brittain, J. H. Manchester's Contribution to the Chemistry of the Nineteenth Century. 'Trans. Rochdale Lit. and Sci. Soc.' ix. 26-29. 1908.

Hall, Henry. Coal Dust to date, and its Treatment with Calcium Chloride. 'Trans. Inst. Min. Eng.' xxxvi. 500-522. 1908.

Jowett, F. Nitro-Bacterine. 'Bradford Scientific Journal,' ii. 181-182. 1908.

Kocks, A. Victor (Midland Inst. Eng.). The Recovery of Bye-products from the Distillation of Coal. 'Trans. Inst. Min. Eng.' xxxvi. 326-336. 1909.

Purcell, Marmaduke F. The Utilisation of Sewage for the Production of Crude Oil and Ammonia. 'Trans. Inst. Min. Eng.' xxxv. 537-544. 1908.

Stanley, G. H. (N. England Inst.) Note on the Effect of an Igneous Dyke on a Natal Coal-Seam. 'Trans. Inst. Min. Eng.' xxxvi. 220-221. 1909.

Section C.—Geology.

Abbott, W. J. Lewis. The Pleistocene Vertebrates of South-East England, 'Trans. S. E. Union,' 1908, 96-113. 1908.

Barke, F. Geological Report. 'Trans. N. Staffs F. C.' xliii. 109-111. 1909.

Beasley, Henry C. Some Markings, other than Footprints, in the Keuper Sandstone and Marls. 'Proc. Liverpool Geol. Soc.' x. 262-275. 1908.

Burnet, Arthur. Notes on the Upper Chalk of Lincolnshire. 'Trans. Leeds Geol. Assoc.' xiv. 8-10. 1909.

—— Note on some Neolithic Flakes from Two Localities in East Lincolnshire. 'Trans. Leeds Geol. Assoc.' xiv. 32-33. 1909.

—— Notes on the Microscopic Aspects of some Cretaceous Rocks. 'Trans. Leeds Geol. Assoc.' xiv. 42-43. 1909.

Burton, F. M. How the Land between Gainsborough and Lincoln was Formed. (Presidential Address, 1895.) 'Trans. Lincolnshire Nat. Union, 1908,' 263-273. 1909.

Cadman, John. Mineral Resources of Trinidad. 'Trans. Inst. Min. Eng.' xxxv. 453-475. 1908.

Cameron, A. C. G. The Sarsens or Greywether Sandstones at Staple Fitzpaine, near Taunton. 'Proc. Somersetshire Arch. N. H. Soc.' liv. Part ii., 153-159. 1909.

Carruthers, E. G., and H. B. Muff. The Lower Palæozoic Rocks around Killary Harbour. 'Irish Naturalist,' xviii. 7-11. 1909.

Clough, C. T., and James Kirkpatrick (Min. Inst. Scotland). Scottish 'Eenie' Coal. 'Trans. Inst. Min. Eng.' xxxvii. 2-11. 1909.

Cobbold, E. S. The Geological Work of the Club, 1907. 'Trans. Caradoc and Severn Valley F. C.' iv. 203-205. 1909.

Cope, Thomas H. Some Comparisons in the Weathering of Basalt. 'Proc. Liverpool Geol. Soc.' x. 236-241. 1908.

Culpin H. Marine and other Fossils in the Yorkshire Coal Measures above the Barnsley Seam. 'Proc. Yorkshire Geol. Soc.' xvi. 321-334. 1909.

Dalton, W. H. Wells on Foulness Island, Ancient and Modern. 'Essex Naturalist,' xv. 118-125. 1908.

—— Post-glacial Beds in Mersea, Essex. 'Essex Naturalist,' xv. 136-137. 1908.

Drake, Henry Charles. Unrecorded Cephalopods from the Yorkshire Oolites. 'The Naturalist for 1908,' 296-297. 1908.

—— Remains of a Chimæroid Fish from the Coral Rag of North Grimston. 'The Naturalist for 1909,' 196. 1909.

Durnford, H. St. John. Geological Notes on a Deep Boring near Selby. 'Proc. Yorkshire Geol. Soc.' xvi. 337-346. 1909.

Dwerryhouse, Dr. A. R. Presidential Address. 'Proc. Liverpool Geol. Soc.' x. 215-285. 1908.

—— Notes on a Junction of Coal Measures and Millstone Grit at Hawkesworth Quarry, Horsforth. 'Proc. Yorkshire Geol. Soc.' xvi. 391-392. 1909.

Egglestone, W. M. (N. England Inst. Eng.) The Occurrence and Commercial Uses of Fluorspar. 'Trans. Inst. Min. Eng.' xxxv. 236-262. 1908.

Elger, Frank. *Hudlestonia sinon* Bayle, from the Blea Wyke Beds, Yorkshire. 'The Naturalist for 1908,' 435. 1908.

—— The Glaciation of North Cleveland. 'Proc. Yorkshire Geol. Soc.' xvi. 372-382. 1909.

Geikie, Sir Archibald. Presidential Address: The Weald. 'Trans. S.E. Union, 1908,' 1-20. 1908.

Ghose, A. (Manchester Geol. Min. Soc.) The Mode of Occurrence of Manganite in the Manganese Ore Deposits of the Sandur State, Bellary, Madras, India. 'Trans. Inst. Min. Eng.' xxxv. 685-691. 1908.

Gregory, E. E. The Later Yellow Boulder Clay of Airedale. 'Bradford Scientific Journal,' ii. 187-189. 1908.

Gregory, Prof. J. W. (Min. Inst. Scotland.) What is a Mineral? 'Trans. Inst. Min. Eng.' xxxvii. 13-34. 1909.

Harker, Thomas (N. England Inst. Eng.). Flinty Chert, Hornstone, &c. 'Trans. Inst. Min. Eng.' xxxvi. 231-232. 1909.

Hassam, A. (N. Staff. Inst. Eng.) Geological and Mining Notes on China. 'Trans. Inst. Min. Eng.' xxxvi. 353-364. 1909.

Hawkesworth, E. Details of a Boring near Barwick-in-Elmet. 'Trans. Leeds Geol. Assoc.' xiv. 40-42. 1909.

Hickling, George (Manchester Geol. Min. Soc.). China-clay: its Nature and Origin. 'Trans. Inst. Min. Eng.' xxxvi. 10-33. 1909.

Hind, Dr. Wheelton. The Present State of our Knowledge of Carboniferous Geology. 'The Naturalist for 1909,' 149-156, 163-170. 1909.

—— Description of Two New Species of Lamellibranchs from Marine Bands of the Yorkshire Coalfield. 'Proc. Yorkshire Geol. Soc.' xvi. 335-336. 1909.

—— Littleshall Hill. 'Trans. N. Staffs. F. C.' xliii. 112-115. 1909.

Hinde, Dr. George J., and Frank Gossling. Fossils from the Chalk exposed in a Road-trench near Croham Hurst, South Croydon. 'Trans. Croydon N. H. Sci. Soc. 1907-1908,' 183-184. 1908.

Holgate, Benjamin. A Description of Six Sections in the Lower Coal Measures of Leeds. 'Trans. Leeds Geol. Assoc.' xiv. 53-58. 1909.

Howarth, J. H. The Ice-borne Boulders of Yorkshire (*continued*). 'The Naturalist for 1908,' 219-214, 245-252. 1908.

Hughes, Prof. T. McKenny. Ingleborough: Part VI. The Carboniferous Rocks. 'Proc. Yorkshire Geol. Soc.' xvi. 253-320. 1909.

Jackson, J. L. S. Report of Geological Section. 'Report Belfast Nat. F. C.' vi. 8-10. 1908.

Johns, Cosmo. Some Undescribed Faults in the Settle-Malham Area. 'Proc. Yorkshire Geol. Soc.' xvi. 393-402. 1909.

Jukes-Browne, A. J. The Burning Cliff and the Landslip at Lyme Regis. 'Proc. Dorset N. H. A. F. C.' xxix. 153-160. 1908.

Kendall, Prof. P. F. Reptilian Footprints in the Lower Oolites at Saltwick. 'The Naturalist for 1908,' 384. 1908.

Kilroe, J. R. The Shell-bearing Drifts of Co. Dublin. 'Irish Naturalist,' xvii. 115-118. 1908.

Knowles, Sir Lees (Manchester Geol. Min. Soc.). Our Steam Coal and its Uses. (Presidential Address.) 'Trans. Inst. Min. Eng.' xxxvi. 273-284. 1909.

Lane, Rev. G. J., and T. W. Saunders. Fossil Plants from the Marske and Upleatham Quarries, Yorkshire. 'The Naturalist for 1909,' 81-82. 1909.

Lomas, J. The Mineralogical Constitution of the Storeton Sandstone. 'Proc. Liverpool Geol. Soc.' x. 242-247. 1908.

—— On a Marine Peat from the Union Dock, Liverpool. 'Proc. Liverpool Geol. Soc.' x. 248. 1908.

McAldowie, Dr. A. M. The Life History of the River Trent. 'Trans. N. Staffs. F. C.' xliii. 116-126. 1909.

Moring, P. Recent Discoveries in Fossil Plants. 'Trans. East Kent Sci. N. H. Soc.' viii. 7-8. 1909.

Parker, William A. Fossil Arthropoda and Pisces from Middle Coal Measures of Sparth, Rochdale. 'Trans. Rochdale Lit. and Sci. Soc.' ix. 64-76. 1908.

Reade, T. Mellard. Post-Glacial Beds at Great Crosby as disclosed by the New Outfall Sewer. 'Proc. Liverpool Geol. Soc.' x. 249-261. 1908.

—— and Philip Holland. Analyses of Longmyndian Rocks. 'Proc. Liverpool Geol. Soc.' x. 276-287. 1908.

Reed, F. R., and S. H. Reynolds. Silurian Fossils from certain Localities in the Tortworth Inlier. 'Proc. Bristol Nat. Soc.' ii. 32-40. 1908.

Reynolds, S. H. Fish Teeth and Spines from the Carboniferous Limestone of the Bristol District. 'Proc. Bristol Nat. Soc.' ii. 41-43. 1908.

Rowley, Walter. Notes on the Development of the Yorkshire Coalfield in the Neighbourhood of Doncaster. 'Proc. Yorkshire Geol. Soc.' xvi. 403-404. 1909.

Sandberg, Dr. C. G. S. The Oil Prospects of Central British South Africa. 'Trans. Inst. Min. Eng.' xxxv. 545-558. 1908.

S[heppard], T. Footprints in a Yorkshire Sandstone. 'The Naturalist for 1908,' 300-301. 1908.

Smythe, Dr. J. A. The Glacial Phenomena of the Country between the Tyne and the Wansbeck. 'Trans. Northumberland N. H. Soc.' iii. 79-109. 1908.

Stenhouse, T. Some Underground Waters of Rochdale and Neighbourhood. 'Trans. Rochdale Lit. Sci. Soc.' ix. 30-36. 1908.

Storrie, John, and F. T. Howard. Geology of the Roath Park, Cardiff. 'Trans. Cardiff Nat. Soc.' xl. 18-25. 1908.

Strachan, James. The Origin and Formation of Zeolites in Basalt. 'Proc. Belfast Nat. F. C.' vi. 92-98. 1908.

Tutcher, J. W. The Strata exposed in constructing the Felton to Avonmouth Railway. 'Proc. Bristol Nat. Soc.' ii. 5-21. 1908.

Tyrrell, J. B. Cobalt and Northern Ontario. 'Trans. Inst. Min. Eng.' xxxv. 488-500. 1908.

Wainewright, Wilfrid B. (Manchester Geol. Min. Soc.) Borate Deposits of California. 'Trans. Inst. Min. Eng.' xxxvii. 156-162. 1909.

Wedd, C. B., and G. Cooper Drabble. The Fluorspar Deposits of Derbyshire. 'Trans. Inst. Min. Eng.' xxxv. 501-535. 1908.

Wilmore, A. Notes on the Geology of Thornton, Marton, and Broughton-in-Craven, Yorkshire. 'Proc. Yorkshire Geol. Soc.' xvi. 347-371. 1909.

Woodward, Dr. Henry. On a Carboniferous Trilobite from Angram, in Nidderdale. 'Trans. Leeds Geol. Assoc.' xiv. 10-12. 1908.

Woolacott, Dr. David. Preliminary Note on a Case of Thrust and Crush Brecciation in the Magnesian Limestone, Co. Durham. 'Trans. Northumberland N. H. Soc.' iii. 46-48. 1908.

Wrench, E. M. Observations on the Effects of Glaciers in Derwent Valley, Derbyshire. 'Journal Manchester Geog. Soc.' xxiv. 1-4. 1908.

Yelland, W. Fossil Hunting. 'Trans. Caradoc and Severn Valley F. C.' iv. 228-233. 1909.

Section D.—Zoology.

Adam, J. C. The Bird Life of an Outer Island. 'Trans. Edinburgh Field Nat. and Mic. Soc.' vi. 1-19. 1908.

Adams, J. On the Division of Ireland into Biological Sub-provinces. 'Irish Naturalist,' xvii. 145-151. 1908.

—— Supplementary Note. 'Irish Naturalist,' xviii. 1-2. 1909.

Adams, James. Further Note on the Mygale Spider. 'Trans. Edinburgh Field Nat. Mic. Soc.' vi. 81-82. 1908.

Adamson, Lieut.-Col. C. H. E. Catalogue of Butterflies collected in Burmah. 'Trans. Northumberland N. H. Soc.' iii. 116-148. 1908.

Ash, F. W. The Evolution of the Cetacean Tail Fin. 'Trans. N. Staffs. F. C.' xliii. 78-82. 1909.

Bagnall, Richard S. Records of some Irish Woodlice; with Note on *Eluma purpurascens*. 'Irish Naturalist,' xvii. 259-260. 1908.

—— *Cryptothrips dentipes*, a Genus and Species of Thysanoptera new to the British Isles. 'Irish Naturalist,' xviii. 41. 1909.

—— On some Terrestrial Isopods from the Glasnevin Botanic Gardens, Dublin. 'Irish Naturalist,' xviii. 42-44. 1909.

—— On some New Genera and Species of Thysanoptera. 'Trans. Northumberland N. H. Soc.' iii. 183-217. 1908.

—— The Bristletails (*Thysanura*) of the Derwent Valley. 'Trans. Vale of Derwent Nat. Field Club,' i. 26-30. 1908.

Bird, Charles. Natural History Notes on the Tropics. 'Rochester Naturalist,' iv. 17-24. 1908.

Blackburn, Rev. E. P. Notes on the Mollusca taken from British Barrows in East Yorkshire. 'The Naturalist for 1908,' 417-419. 1908.

Bladen, W. Wells. Bird Notes (1907-1908), chiefly taken at Stone. 'Trans. N. Staffs. F. C.' xliii. 83-95. 1909.

Blathwayt, Rev. F. L. Notes on the Birds of a Ballast Pit. 'Trans. Lincolnshire Nat. Union, 1908,' 222-229. 1909.

Booth, Harry B. Notes on the Summer Migratory Birds for 1907-8. 'Bradford Scientific Journal,' ii. 171-181. 1908.

—— The Changing Distribution of the Long-tailed Titmouse in the West Riding. 'The Naturalist for 1909,' 55-57. 1909.

—— Paucity of Redwings in the West Riding. 'The Naturalist for 1909,' 78-79. 1909.

Bostock, E. D. Entomological Report. 'Trans. N. Staffs. F. C.' xlii. 82-84. 1908.

—— Entomological Report. 'Trans. N. Staffs. F. C.' xliii. 96-97. 1909.

Bradford Natural History and Microscopical Society. Natural History Observations in the Bradford District for the year ending November 30, 1908. 'Bradford Scientific Journal,' ii. 193-204. 1909.

Brown, James M. Freshwater Rhizopods from the Sheffield District. 'The Naturalist for 1909,' 105-108. 1909.

Bryan, B. Notes on the Habits of the Blind-worm and Common Lizard. 'Trans. N. Staffs. F. C.' xlii. 74-81. 1908.

Burton, F. M. Some Lincolnshire Boulders. 'The Naturalist for 1909,' 93-96. 1909.

—— Notes on Rooks. 'The Naturalist for 1909,' 146-148. 1909.

Butterfield, E. P. Distribution of the Stonechat in Yorkshire during the Breeding Season. 'Bradford Scientific Journal,' ii. 250-252. 1909.

Butterfield, Rosse. Notes on Bees and Wasps during May and June near Bradford. 'Bradford Scientific Journal,' ii. 151-153. 1908.

Butterfield, W. R., and W. H. Bennett. On some Spiders collected in the District around Hastings. 'Trans. S. E. Union, 1908,' 40-44. 1908.

Calman, Dr. W. T. On a Parasitic Copepod from *Cephalodiscus*. 'Trans. S. African Phil. Soc.' xvii. 177-184. 1908.

CARADOC AND SEVERN VALLEY FIELD CLUB. Zoological and Entomological Notes. 'Record of Bare Facts,' No. 18, 17-27. 1909.

CARPENTER, Prof. G. H. On Two Collembola New to the Britannic Fauna. 'Irish Naturalist,' XVII. 174-179. 1908.

CARTER, C. S. Local Distribution of Colour and Band Formulæ in *Helix nemoralis*. 'Trans. Lincolnshire Nat. Union, 1908,' 304-305. 1909.

CATON, Rev. R. B. Arrival of Migratory Birds at Great Fakenham, Suffolk. 'Trans. Norfolk and Norwich Nat. Soc.' VIII. 535. 1908.

CLARK, Dr. JAMES. Bird Migration in Cornwall. 'Journal Royal Inst. Cornwall,' XVII. 274-293. 1908.

COLGAN, NATHANIEL. Dublin Marine Biological Committee: General Account of Dredging Operations, 1907; with Special Notes on the Mollusca. 'Irish Naturalist,' XVII. 105-114. 1908.

CONNOLD, EDWARD. Some Local Marine Sponges. 'Trans. S.E. Union, 1908,' 96-91. 1908.

FORREST, H. E. Zoology, 1907. 'Trans. Caradoc and Severn Valley F. C.' IV. 201-202. 1909.

—— Vertebrates of Wales and Ireland. 'Trans. Caradoc and Severn Valley F. C.' IV. 245-248. 1909.

—— The Origin of British 'Wild' Cattle. 'Trans. Caradoc and Severn Valley F. C.' IV. App. 1*a*-9*a*. 1909.

—— The Origin of British 'Wild' Cattle. 'The Naturalist for 1908,' 328-332, 361-366. 1908.

FOSTER, NEVIN H. Report of Zoological Section. 'Report Belfast Nat. F. C.' VI. 13-17. 1908.

—— *Armadillidium pictum*, Brandt: an Addition to the Britannic Fauna. 'Irish Naturalist,' XVII. 135-136. 1908.

FREMLIN, H. S. The Effects of Physical and Chemical Agencies on Lepidoptera. 'Proc. South London Ent. N. H. Soc. 1908-9,' 1-6. 1909.

—— Insects as Carriers of Disease. 'Proc. South London Ent. N. H. Soc. 1908-1909,' 14-15. 1909.

FRIEND, Rev. H. HILDERIC. Recollections of Annelid Hunting around Bradford. 'Bradford Scientific Journal,' II. 231-234. 1909.

GEORGE, C. F. Some British Earthmites (*Trombidiida*). 'The Naturalist for 1908 and 1909,' 333-336, 377, 452-454, 1908; 87-88, 194-195, 1909.

GIBBS, A. E., and P. J. BARRAUD. A Preliminary List of Hertfordshire Diptera. 'Trans. Herts N. H. Soc.' XIII. 249-276. 1908.

GILCHRIST, Dr. J. D. F. New Forms of the Hemichordata from South Africa. 'Trans. S. African Phil. Soc.' XVII. 151-176. 1908.

HALBERT, J. N. The Occurrence of *Paromola Cuvieri* in Irish Waters. 'Irish Naturalist,' XVII. 129-132. 1908.

HANN, Rev. ADAM. Marine Shells: their Variety and Beauty. 'Trans. Rochdale Lit. Sci. Soc.' IX. 1-7. 1908.

HARTING, J. E. Eagles about Tiptree Heath. 'Essex Naturalist,' XV. 178. 1908.

HENDERSON, ROBERT. The Diptera of Clyde. (Second List.) 'Trans. Glasgow N. H. Soc.' VIII. 7-22. 1908.

HERON-ALLEN, EDWARD, and ARTHUR EARLAND. On a New Species of *Technitella* from the North Sea; with some Observations upon Selective Power as exercised by certain Species of Arenaceous Foraminifera. 'Journal Quekett Mic. Club,' X. 403-412. 1909.

HEY, Rev. W. C. Humble Bees at West Ayton, Yorks. 'The Naturalist for 1908,' 449-451. 1908.

—— Wasps at West Ayton, Yorks. 'The Naturalist for 1909,' 53-54. 1909.

—— The Hornet in Yorkshire. 'The Naturalist for 1909,' 80. 1909.

HILTON, A. E. On the Cause of Reversing Currents in the Plasmodia of Mycetozoa. 'Journal Quekett Mic. Club,' X. 263-270. 1908.

Hull, Rev. J. E. Allendale Spiders. 'Trans. Northumberland N. H. Soc.' iii. 110-115. 1908.

Jackson, A. Randell. On some Rare Arachnids captured during 1907. 'Trans. Northumberland N. H. Soc.' iii. 49-78. 1908.

—— A Note on some Rare Spiders from the Derwent Valley. 'Trans. Vale of Derwent Nat. Field Club,' i. 31-32. 1908.

Jackson, J. Wilfrid. Notes on Cheshire Land and Freshwater Mollusca. 'The Naturalist for 1908,' 436. 1908.

Jacubowa, Lydia. A New Species of Planocera (*P. Gilchristi*) from South Africa. 'Trans. S. African Phil. Soc.' xvii. 145-149. 1908.

John, Dr. Microscopical Report. 'Trans. N. Staffs. F. C.' xliii. 108. 1909.

Johnson, Rev. W. F. Entomological Notes during 1908. 'Irish Naturalist,' xviii. 69-72. 1909.

Johnstone, Mary A. Notes on Chamæleons. 'Bradford Scientific Journal,' ii. 136-137. 1908.

Jones, A. H. Notes on Hungarian Butterflies. 'Proc. South London Ent. N. H. Soc. 1908-1909,' 11-13. 1909.

Kerr, Prof. J. Graham. Note on the Pelagic Fauna observed off the West Coast of Arran during the months of August and September 1905. 'Trans. Glasgow N. H. Soc.' viii. 5-7. 1908.

Lebour, Miss Marie V. Trematodes of the Northumberland Coast. No. ii. 'Trans. Northumberland N. H. Soc.' iii. 28-45. 1908.

Leney, Frank. Some Additions to the Norwich Castle Museum in 1907. 'Trans. Norfolk and Norwich Nat. Soc.' viii. 596-598. 1908.

Long, Dr. Sydney H. The Birds of Handa (Presidential Address). 'Trans. Norfolk and Norwich Nat. Soc.' viii. 499-516. 1908.

Margerison, Samuel. Hawks and Falconry. 'Bradford Scientific Journal,' ii. 148-150. 1908.

Masefield, J. R. B. Zoological Report. 'Trans. N. Staffs. F. C.' xlii. 61-67. 1908; xlii. 68-77. 1909.

—— Staffordshire Bats. 'Trans. N. Staffs. F. C.' xlii. 68-73. 1909.

Mason, G. W. The Lepidoptera of Lincolnshire. Part II. 'Trans. Lincolnshire Nat. Union, 1908,' 230-262. 1909.

Mayfield, A. The Marine and Estuarine Mollusca of Suffolk. 'Journal Ipswich F.C.' i. 5-9. 1908.

Meyrick, E. Report of the Entomological Section. 'Report Marlb. Coll. N. H. Soc.' No. 57, 45-52. 1909.

—— Ornithological List. 'Report Malb. Coll. N. H. Soc.' No. 57, 53-56. 1909.

Morley, Claude. The Insects of the Breck. 'Trans. Norfolk and Norwich Nat. Soc.' viii. 579-586. 1908.

Morley, E. Notes on the Lepidoptera of South Yorkshire in 1908. 'The Naturalist for 1909,' 17-20. 1909.

Oldham, Chas. Notes on Cheshire Land and Freshwater Mollusca. 'The Naturalist for 1908,' 253-261. 1908.

Pack-Beresford, D. R. *Eluma purpurascens:* a Woodlouse new to the British Isles. 'Irish Naturalist,' xvii. 255-258. 1908.

—— and Nevin, H. Foster. On the Distribution of Woodlice in Ireland as known at the end of 1908. 'Irish Naturalist,' xviii. 92-93. 1909.

Patience, Alexander. On the occurrence of *Idothea neglecta*, G. O. Sars, and *Idothea viridis* (Slabber), within the Clyde Sea Area, and some Notes on other Clyde Species of Idothea. 'Trans. Glasgow N. H. Soc.' viii. 42-46. 1908.

—— Some Notes on the Distribution of the Clyde Crangonidæ. 'Trans. Glasgow N. H. Soc.' viii. 64-71. 1908.

—— On the Occurrence of *Gobius orca*, Collett, within the Clyde Sea Area. 'Trans. Glasgow N. H. Soc.' viii. 74-76. 1908.

PATIENCE, ALEXANDER. On some Terrestrial Isopods new to the Clyde Faunal Area, and some Notes on the Distribution of the Rarer Species. 'Trans. Glasgow N. H. Soc.' VIII. 80-96. 1908.

PATTEN, Dr. C. J. The Migratory Movements of certain Shore Birds as observed on the Dublin Coast. 'The Naturalist for 1909,' 48-52, 83-86. 1909.

PATTERSON, ARTHUR H. Natural History Notes from Yarmouth. 'Trans. Norfolk and Norwich Nat. Soc.' VIII. 604-615. 1908.

PEACOCK, MAX. The Birds of North-West Lindsey. 'The Naturalist for 1908,' 272-277, 399-402. 1908.

PEARCEY, F. GORDON. On the Genus *Botellina* (Carpenter), with a Description of a New Species. 'Trans. S. African Phil. Soc.' XVII 185-194. 1908.

PÉRINGUEY, L. Catalogue of the Coleoptera of South Africa. Additions and Corrections. 'Trans. S. African Phil. Soc.' XIII. 547-752. 1908.

PICKARD-CAMBRIDGE, Rev. O. On New and Rare British Arachnida observed in 1907. 'Proc. Dorset N. H. A. F. C.' XXIX. 161-194. 1908.

—— on *Erigone spinosa* Cambr., a Spider new to the British Fauna. 'The Naturalist for 1908,' 378-379. 1908.

PROGER, T. W., and D. R. PATERSON. Ornithological Notes. 'Trans. Cardiff Nat. Soc.' XL. 43-46. 1908; XLI. 51-53. 1909.

PURDY, R. J. W. The Occasional Luminosity of the White Owl (*Strix flammea*). 'Trans. Norfolk and Norwich Nat. Soc.' VIII. 547-552. 1908.

REGAN, C. TATE. The Char of Ireland. 'Irish Naturalist,' XVIII. 3-6. 1909.

RIDDELL, W. *Spinther oniscoides*, Johnston. 'Irish Naturalist,' XVIII. 101-108. 1909.

ROBERTSON, JOHN. The Birds of Rouken Glen Park. 'Annals Andersonian Nat. Soc.' III. 63-70. 1908.

—— Nesting Dates of some of the Waders. 'Trans. Glasgow N. H. Soc.' VIII. 62-64. 1908.

—— Little Stint (*Tringa minuta*) at Balgray Reservoir. 'Trans. Glasgow N. H. Soc.' VIII. 76-77. 1908.

—— The Common Sandpiper (*Totanus hypoleucus*). 'Trans. Glasgow N. H. Soc.' VIII. 77-79. 1908.

ROEBUCK, W. DENISON. Mollusca at Brafferton. 'The Naturalist for 1908,' 298-299. 1908.

—— Census of Lincolnshire Land and Freshwater Mollusca to end of 1908. 'Trans. Lincolnshire Nat. Union, 1908,' 306-311. 1909.

ROSSETER, T. B. *Hymenolepis farciminalis.* 'Journal Quekett Mic. Club,' x. 295-310. 1908.

—— On *Holostomum excisum* (Linstow, 1906) and the Development of a Tetracotyliform Larva to a *Holostomum* sp. 'Journal Quekett Mic. Club,' x. 385-392. 1909.

—— *Hymenolepis acicula sinuata,* a new Species of Tapeworm. 'Journal Quekett Mic. Club,' x. 393-402. 1909.

ROUSSELET, CHARLES F. Note on the Rotatorian Fauna of Boston, with Description of *Notholca bostoniensis,* s.n. 'Journal Quekett Mic. Club,' x. 335-340. 1908.

RUSSELL, E. S. Occurrence of *Gonactinia prolifera,* Sars, in the Firth of Clyde. 'Trans. Glasgow N. H. Soc.' VIII. 27-30. 1908.

ST. QUINTIN, W. H. Notes on the Life History of the Leaf Insect. 'The Naturalist for 1908,' 235-238. 1908.

—— Notes on a Flock of Pallas' Sand Grouse in East Yorks. 'The Naturalist for 1908,' 420-421. 1908.

—— The Gargeny breeding in East Yorkshire. 'The Naturalist for 1909,' 38. 1909.

SCOURFIELD, D. J. The Locomotion of Microscopic Aquatic Organisms. 'Journal Quekett Mic. Club,' x. 357-366. 1909.

SERVICE, ROBERT. Mole Variation. 'Trans. Edinburgh Field Nat. and Mic. Soc.' VI. 64-65. 1908.

—— The Waders of Solway. 'Trans. Glasgow N. H. Soc.' VIII. 46-60. 1908.

SHEPPARD, T. Hornsea: its Mere and Coastline. 'The Naturalist for 1908,' 302-310. 1908.

—— On a Specimen of *Eryon antiquus* Broderip, from the Yorkshire Lias. 'The Naturalist for 1909,' 8-10. 1909.

SICH, ALFRED. House Moths. 'Proc. South London Ent. N. H. Soc. 1908-9,' 7-10. 1909.

—— Annual Address. 'Proc. South London Ent. N. H. Soc. 1908-9,' 30-43. 1909.

SIKES, F. H. Land and Freshwater Shells, Rochester District. 'Rochester Naturalist,' IV. 41-43. 1909.

—— Ornithological Eccentricities. 'Rochester Naturalist,' IV. 49-59. 1909.

SMITH, FRANK P. Some British Spiders taken in 1908. 'Journal Quekett Mic. Club,' x. 311-334. 1908.

SOAR, D. D. The Genus Hydrachna. 'Journal Quekett Mic. Club,' x. 271-282. 1908.

SOUTHERN, ROWLAND. Dublin Marine Biology Committee: A New Irish Gephyrean. 'Irish Naturalist,' XVII. 171-173. 1908.

—— The Gordii of Ireland. 'Irish Naturalist,' XVIII. 115-117. 1909.

SPEEDY, TOM. British Birds of Prey. 'Trans. Edinburgh Field Nat. Mic. Soc.' VI. 20-30. 1908.

STAINFORTH, T. Coleoptera new to Yorkshire. 'The Naturalist for 1908,' 277-278. 1908.

STELFOX, A. W. Additional Notes on the Land and Freshwater Mollusca of North-West Donegal. 'Irish Naturalist,' XVIII. 96-92. 1909.

TEMPERLEY, GEORGE W. The Northumberland Coast in September: an Ornithological Ramble. 'Trans. Northumberland N. H. Soc.' III. 170-182. 1908.

THOMSON, Dr. D. G. Notes on a Tame Hare. 'Trans. Norfolk and Norwich Nat. Soc.' VIII. 540-546. 1908.

THORNLEY, Rev. A., and W. WALLACE. Lincolnshire Coleoptera. (Second Paper.) 'Trans. Lincolnshire Nat. Union, 1908,' 274-288. 1909.

TICEHURST, N. F. Birds exhibited at the Congress Museum. 'Trans. S.E. Union, 1908,' 92-95. 1908.

WADE, E. W. A Yorkshire Peregrine. 'The Naturalist for 1908,' 360. 1908.

—— On the Status of the Stone Curfew in Yorkshire. 'The Naturalist for 1909,' 11-16. 1909.

WALKER, JAMES J. First Supplement to the Preliminary List of the Coleoptera of the Oxford District, published in the Report for 1906. 'Report Ashmolean N. H. Soc. for 1907,' 51-60. 1908.

—— Interim Report on Local Coleoptera. 'Report Ashmolean Nat. Hist. Soc. 1908,' 44. 1909.

WALLIS, EUSTACE F. The Lepidoptera of Northamptonshire. 'Journal Northants N. H. Soc.' XIV. 231-238. 1908; 273-281. 1909.

WELCH, R. Land-shell Rain-water at Horn Head, Co. Donegal. 'Irish Naturalist,' XVIII. 113-115. 1909.

WESCHE, W. The Proboscis of the Blowfly, *Calliphora erythrocephala*, Mg.: a Study in Evolution. 'Journal Quekett Mic. Club,' x. 283-294. 1908.

—— The Structure of the Eye-surface, and the Sexual Differences in the Eyes in Diptera. 'Journal Quekett Mic. Club,' x. 367-384. 1909.

WHITTAKER, ARTHUR. Notes on Bats. 'The Naturalist for 1909,' 71-77. 1909.

WHITTAKER, OSCAR. A preliminary Catalogue of the Hemiptera-Homoptera of Lancashire and Cheshire. 'Proc. Lancashire and Cheshire Ent. Soc. 1908,' 19-22. 1909.

WICKES, W. H. Pebble-swallowing Animals (a Sequel to 'The Rhætic Bone-beds'). 'Proc. Bristol Nat. Soc.' II. 25-31. 1908.

WILLIAMS, ALEXANDER. Wild Bird Protection in Co. Dublin. 'Irish Naturalist,' XVII. 119-122. 1908.

—— Bird Life in Dublin Bay: the Passing of Clontarf Island. 'Irish Naturalist,' XVII. 165-170. 1908.

WILSON, Rev. ALEX. S. Galls, Gallmakers, and Cuckoo Flies. 'Trans. Edinburgh Field Nat. Min. Soc.' VI. 30-48. 1908.

WILSON, WALTER. Albino Carrion Crow in Yorkshire. 'The Naturalist for 1909,' 131. 1909.

WINTER, W. P. A Note on the Cockchafer. 'Bradford Scientific Journal,' II. 215-217. 1909.

—— Arachnida: the Spiders of the Bradford Area. 'Bradford Scientific Journal,' II. 245-249. 1909.

WISHART, R. S. Appleringie, *Artemisia abrotonum*, Linn. 'Trans. Glasgow N. H. Soc.' VIII. 22-27. 1908.

WOODRUFFE-PEACOCK, E. A. Thrush Stones and *Helix nemoralis* L. 'The Naturalist for 1909,' 171-174. 1909.

WRIGHT, MAX A. Bird Protection around Cardiff: some Existing Anomalies. 'Trans. Cardiff Nat. Soc.' XL. 37-42. 1908.

Section E.—GEOGRAPHY.

ANDERSON, Dr. TEMPEST. The Volcanoes of Guatemala. 'Trans. Liverpool Geog. Soc. 1908,' 11-15. 1909.

ASCOLI, W. S. Guatemala: Travels and Experiences. 'Journal Manchester Geog. Soc.' XXIV. 97-126. 1908.

BROWNE, Prof. E. G. Persian Aspirations. 'Journal Tyneside Geog. Soc.' V. 5-9. 1909.

DANN, E. W. The Historical Geography of the Danube. 'Journal Manchester Geog. Soc.' XXIV. 127-130. 1908.

FAWCUS, W. P. JAMES. Experiences in Zanzibar and East Africa. 'Journal Manchester Geog. Soc.' XXIV. 5-11. 1908.

HOBSON, BERNARD. With the International Geological Congress in Mexico. 'Journal Manchester Geog. Soc.' XXIV. 41-59. 1908.

MARTIN, EDWARD A. Some Considerations concerning Dewponds. 'Trans. S.E. Union, 1908,' 66-85. 1908.

MOORE, Dr. J. MURRAY. A Cruise in the Baltic Sea and a Visit to Moscow. 'Trans. Liverpool Geog. Soc. 1908,' 16-22. 1909.

MOUNTMORRES, Viscount. The Unknown Heart of Central Africa. 'Journal Manchester Geog. Soc.' XXIV. 12-31. 1908.

PULLEN-BURRY, Miss H. The Bismarck Archipelago. 'Trans. Liverpool Geog. Soc. 1908,' 7-10. 1909.

WILSON, THOMAS. Queensland in 1906. 'Proc. Glasgow R. Phil. Soc.' XXXIX. 155-166. 1908.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

BELLOC, HILAIRE. The Elasticity of a Tariff. 'Trans. Manchester Stat. Soc. 1907-1908,' 37-58. 1908.

BOOTH, A. H. The Non-Commission Paying Life Offices. 'Trans. Manchester Stat. Soc. 1907-1908,' 77-120. 1908.

Brownlee, Dr. John. Germinal Vitality: a Study of the Growth of Nations as an Instance of a hitherto undescribed Factor in Evolution. 'Proc. Glasgow R. Phil. Soc.' xxxix. 180-204. 1908.

Chart, D. A. Two Centuries of Irish Agriculture. 'Journal Stat. Soc. Ireland,' xii. 162-174. 1908.

Dendy, Miss Mary. The Problem of the Feeble-minded. 'Trans. Manchester Stat. Soc. 1907-1908,' 121-147. 1908.

Duncan, Dr. Ebenezer. Some Observations on the Consumption of Alcohol, and on the Comparative Death Rate from Alcoholic Excess in England, Ireland, and Scotland. 'Proc. Glasgow R. Phil. Soc.' xxxix. 167-179. 1908.

Finlay, Rev. T. A. Ethics and Economics of Poor Relief. 'Journal Stat. Soc. Ireland,' xii. 43-51. 1908.

Fraser, William. Fluctuations of the Building Trade, and Glasgow's House Accommodation. 'Proc. Glasgow R. Phil. Soc.' xxxix. 21-40. 1908.

Geoghegan, Hanbury C. A Plea for Irish Mines and Minerals, under an Irish Board, and for Preparation of a Mining Survey. 'Journal Stat. Soc. Ireland,' xii. 141-161. 1908.

Harvey, A. G. C. The Administration of Elementary Education by Great Authorities. 'Trans. Manchester Stat. Soc.' 50-76. 1908.

Latham, Baldwin. A Chapter in the History of Croydon. (President's Address.) 'Proc. Croydon N. H. Sci. Soc. 1907-1908,' cxxxvii.-clxi. 1908.

—— Records concerning the Health of Croydon for the Years 1539 to 1901. 'Proc. Croydon N. H. Sci. Soc. 1907-1908,' clxii.-ccxl. 1908.

Niven, James. Death Rates. 'Trans. Manchester Stat. Soc. 1907-1908,' 1-35. 1908.

Oldham, C. H. The Economics of 'Industrial Revival' in Ireland. 'Journal Stat. Soc. Ireland,' xii. 175-189. 1908.

Roney, Miss. Some Remedies for Overcrowded City Districts. 'Journal Stat. Soc. Ireland,' xii. 52-61. 1908.

Samuels, Arthur W. Some Features in recent Irish Finance. (Presidential Address.) 'Journal Stat. Soc. Ireland,' xii. 1-42. 1908.

Stanuell, Charles A. Irish Forestry and the Land Purchase Acts. 'Journal Stat. Soc. Ireland,' xii. 93-102. 1908.

—— Facilities for Investing in Consols. 'Journal Stat. Soc. Ireland,' xii. 125-140. 1908.

Stevenson, J. V. The Punishment and Prevention of Crime. 'Proc. Glasgow R. Phil. Soc.' xxxix. 1-12. 1908.

Wigg, J. T. Notes on the Herring Fishery of 1907. 'Trans. Norfolk and Norwich Nat. Soc.' viii. 599-603. 1908.

Section G.—Engineering.

Annett, H. C. (N. England Inst. Eng.) The Working of the Inclined Seams in the St. Etienne Coal-field, at the Montrambert and La Béraudière Collieries. 'Trans. Inst. Min. Eng.' xxxvi. 394-425. 1909.

Austin, Lawrence (N. England Inst. Eng.). Demonstration of Rescue Apparatus, Felling, August 31, 1907. 'Trans. Inst. Min. Eng.' xxxv. 210-216. 1908.

Bagnoli, Ugo (N. England Inst.). Repairing Leaky Seams. 'Trans. Inst. Min. Eng.' xxxvi. 213-215. 1909.

Bouchier, Charles F. (Manchester Geol. Min. Soc.) Enlarging an Upcast Furnace Shaft from 10 to 15½ feet in diameter, whilst available for Winding Men and Coal. 'Trans. Inst. Min. Eng.' xxxv. 330-333. 1908.

Budge, G. D., and Peter Dunsire (Min. Inst. Scotland). Sinking Operations at Wellesley New Fitting, Wemyss Collieries. 'Trans. Inst. Min. Eng.' xxxvi. 318-324. 1909.

Caldwell, William. The Working of Oil-shale at Pumpherston. 'Trans. Inst. Min. Eng.' xxxvi. 581-589. 1909.

Chambers, D. M. Notes on the Winning of Crude Oil. 'Trans. Inst. Min. Eng.' xxxv. 559-577. 1908.

Cooper, Francis E. Construction and Maintenance of Carriageways. 'Trans. Liverpool Eng. Soc.' xxix. 101-118. 1908.

Cunliffe, James (S. Staff. and Warw. Inst. Eng.). Methods of Working the Warwickshire Thick Coal at the Hawkesbury Colliery, Bedworth. 'Trans. Inst. Min. Eng.' xxxv. 390-393. 1908.

Dickinson, Joseph (Manchester Geol. Min. Soc.). Deviation of Boreholes. 'Trans. Inst. Min. Eng.' xxxv. 396-398. 1908.

Duncanson, Thomas. Inaugural Address. [Water Supply.] 'Trans. Liverpool Eng. Soc.' xxix. 1-18. 1908.

Fletcher, Leonard B. (Manchester Geol. Min. Soc.) The Patent Keps under the Cages at Chanters Pit, Atherton Collieries. 'Trans. Inst. Min. Eng.' xxxv. 692-694. 1908.

Galloway, Thomas Lindsay (Min. Inst. Scotland). Experiments with Two Electrically-driven Pumps. 'Trans. Inst. Min. Eng.' xxxvi. 82-89. 1909.

Garton, E. (Midland Inst. Eng.) The Regulation of Colliery Electrical Power-station Supply, with special reference to the Tirrill Regulator. 'Trans. Inst. Min. Eng.' xxxvii. 61-78. 1909.

Gemmell, John. The Wemyss Coalfield. 'Trans. Inst. Min. Eng.' xxxvi. 555-568. 1909.

Given, E. C. Submarines and Submersibles. 'Trans. Liverpool Eng. Soc.' xxix. 129-191. 1908.

Gray, F. W., and James McMahon (Midland Inst. Eng.). The Use of Breathing-apparatus at a Mine Fire in Cape Breton, with some Notes on the Central Rescue-station of the Dominion Coal Company, Limited, at Glace Bay, Cape Breton, Nova Scotia. 'Trans. Inst. Min. Eng.' xxxvii. 100-111. 1909.

Habershon, M. H. (Midland Inst. Eng.) Presidential Address. [Coal Mining.] 'Trans. Inst. Min. Eng.' xxxvi. 164-183. 1909.

Hay, W. (Mid. Counties Inst. Eng.) Presidential Address. [Coal Mining.] 'Trans. Inst. Min. Eng.' xxxvi. 132-142. 1909.

—— (Mid. Counties Inst. Eng.). Damage to Surface Buildings caused by Underground Workings. 'Trans. Inst. Min. Eng.' xxxvi. 427-432. 1909.

Hill, H. H. High-speed Steel. 'Trans. Liverpool Eng. Soc.' xxix. 215-220. 1908.

Hindley, Joseph, and John Stoney (Manchester Min. Geol. Soc.). Description of a New Patent Appliance for arresting the Descent of Cages in Shafts, in the event of the Winding-rope Breaking. 'Trans. Inst. Min. Eng.' xxxv. 698-699. 1908.

—— —— (Manchester Geol. Min. Soc.) Stresses on Winding and Conducting Ropes, as used in Mine Shafts. 'Trans. Inst. Min. Eng.' xxxvi. 286-291. 1909.

Holland, Laurence. Brickwork Dams in Thick Coal. 'Trans. Inst. Min. Eng.' xxxvii. 54-59. 1909.

—— (S. Staff. and Warw. Inst. Eng.) Notes on Working the Thick Coal of South Staffordshire and Warwickshire. 'Trans. Inst. Min. Eng.' xxxvii. 46-50. 1909.

Horan, P. (N. Staff. Inst. Eng.) Tapered Timber. 'Trans. Inst. Min. Eng.' xxxvii. 135-140. 1909.

HYSLOP, G. P. (N. Staff. Inst. Eng.) Presidential Address. 'Trans. Inst. Min. Eng.' xxxvi. 236-243. 1909.

—— and J. MAGEE (N. Staff. Inst. Eng.). Notes on certain Alterations to a large Winding Drum. 'Trans. Inst. Min. Eng.' xxxvi. 246-249. 1909.

JONES, GREVILLE. Calcining Kilns. 'Trans. Inst. Min. Eng.' xxxv. 481-487. 1908.

JONES, JOHN PHILIP (Manchester Geol. Min. Soc.). Holywell-Halkyn Tunnel and Mines, Holywell, North Wales. 'Trans. Inst. Min. Eng.' xxxvi. 197-201. 1909.

KAHN, M. A Review of Reinforced Concrete; its Theory and Practice. 'Trans. Liverpool Eng. Soc.' xxix. 19-39. 1908.

KEEFER, FREDERICK. Mining in the Boundary District of British Columbia. 'Trans. Inst. Min. Eng.' xxxv. 580-588. 1908.

KIRKPATRICK, W. D. Electrical Equipment of Ships. 'Trans. Liverpool Eng. Soc.' xxix. 197-208. 1908.

MAVOR, SAM (Min. Inst. Scotland). Note on Timbering Roadways. 'Trans. Inst. Min. Eng.' xxxv. 169-170. 1908.

MILLWARD, A. E. (Manchester Geol. Min. Soc.) Sinking and Tubbing a Well 15 feet in Diameter, and Boring Two Holes 44 inches in diameter, through Gravel, Running-sand, Boulder-clay, and other Measures, at Altham Bridge Pumping Station, near Accrington. 'Trans. Inst. Min. Eng.' xxxv. 400-407. 1908.

MOLLER, W. A. (Mid. Counties Inst. Eng.) Drilling with Bamboo Rods. 'Trans. Inst. Min. Eng.' xxxvi. 437-442. 1909.

O'BRIEN, H. E. Electric Traction on Urban and Inter-Urban Steam Tramways. 'Trans. Liverpool Eng. Soc.' xxix. 333-363. 1908.

PARKIN, JOHN H. The Gorpley Works for the Supply of Water to Todmorden. 'Trans. Liverpool Eng. Soc.' xxix. 69-89. 1908.

PICKERING, W. H. Fence Gates for Pit Cages. 'Trans. Inst. Min. Eng.' xxxv. 271-279. 1908.

RASPASS, J. C. T. (N. Staff. Inst.) Manjak as worked at the Vistabella Mine, Trinidad. 'Trans. Inst. Min. Eng.' xxxvi. 119-124. 1909.

REDFERN, ALFRED (N. Staff. Inst. Eng.). Practical Notes on Deep Shaft-sinking and breaking Ground on the Witwatersrand. 'Trans. Inst. Min. Eng.' xxxv. 358-373. 1908.

RHODES, CHARLES EDWARD. Presidential Address. [Coal-Mining.] 'Trans. Inst. Min. Eng.' xxxv. 445-451. 1908.

ROSS, M. GLEN. Construction and Demolition of Tunnels. 'Trans. Liverpool Eng. Soc.' xxix. 227-257. 1908.

SEABRIDGE, T. S. (N. Staff. Inst.) Spontaneous Combustion. 'Trans. Inst. Min. Eng.' xxxvi. 109-114. 1908.

SIDDALL, F. N. (Mid. Counties Inst. Eng.) Methods of dealing with Gob-fires in the Main Coal-seam at Netherseal Colliery. 'Trans. Inst. Min. Eng.' xxxvi. 454-460. 1909.

SOPWITH, S. F. (S. Staff. Inst. Eng.) An Emergency Pumping-plant at Cannock Chase Colliery. 'Trans. Inst. Min. Eng.' xxxv. 190-197. 1908.

SPENCER, E. D. (Mid. Counties Inst. Eng.) The Cramp Safety Device for attaching to Mine Cages. 'Trans. Inst. Min. Eng.' xxxvi. 156-159. 1909.

STRATHERN, ALEXANDER G. (Min. Inst. Scotland) How Weldless Chains are made. 'Trans. Inst. Min. Eng.' xxxv. 173-181. 1908.

THACKER, S. L. Winding-engine Tests, with Notes and Suggestions on the Design and Testing of Plant. 'Trans. Inst. Min. Eng.' xxxv. 589-654. 1908.

THOMPSON, J. G. (N. England Inst.) The 'Bold' Box-controller and Box-switch. 'Trans. Inst. Min. Eng.' XXXVI. 217-219. 1909.

THOMSON, JAMES G. Deep Diamond-boring at Balfour Mains, Fifeshire. 'Trans. Inst. Min. Eng.' XXXVI. 574-579. 1908.

THORNHILL, W. E. Foryd Viaduct Widening and Cylinder Sinking. 'Trans. Liverpool Eng. Soc.' XXIX. 303-323. 1908.

WALKER, GEORGE BLAKE. On the Practical Use and Value of Colliery Rescue Apparatus, and the Organisation of Rescue Corps. 'Trans. Inst. Min. Eng.' XXXVI. 536-544. 1908.

WATKINSON, Prof. W. H. Steam Superheaters and their Applications. 'Trans. Liverpool Eng. Soc.' XXIX. 267-282. 1908.

WATSON, EDWARD. Coal-Mining on the Kirghese Steppe, in the Akmolinsk District of South-Western Siberia. 'Trans. Inst. Min. Eng.' XXXVII. 124-132. 1909.

WINBORN, ARTHUR T. (Midland Inst. Eng.) Suggestions for the Organisation of Colliery Rescue Brigades. 'Trans. Inst. Min. Eng.' XXXVII. 81-99. 1909.

WINSTANLEY, GEORGE H. (Manchester Geol. Min. Soc.) Suggestions for Winding, with special reference to Ropes, Safety Cages, and Controlling Devices for Colliery Winding Engines. 'Trans. Inst. Min. Eng.' XXXV. 134-155. 1908.

WORDSWORTH, T. H. (Manchester Geol. Min. Soc.) The Lee Safety Appliance for Cages. 'Trans. Inst. Min. Eng.' XXXV. 695-697. 1908.

Section H.—ANTHROPOLOGY.

ARCHIBALD, S. CLAVA. The Stonehenge of Scotland. 'Trans. Edinburgh Field Nat. Mic. Soc.' VI. 55-63. 1908.

ARMSTRONG, A. LESLIE. Two Ancient Burial Cairns on Brimham Moor, Yorkshire. 'The Naturalist for 1909,' 89-92. 1909.

BEDDOE, Dr. JOHN. On an Ancient Skull from the Cave of Lombrive, in the Pyrenees, and a comparatively Modern one from Wiltshire. 'Proc. Bristol Nat. Soc.' II. 22-24. 1908.

BOND, F. BLIGH. Glastonbury Abbey: Report on the Discoveries made during the Excavations of 1908. 'Proc. Somersetshire Arch. N. H. Soc.' LIV. Part II. 109-130. 1909.

BRIGG, J. J. Prehistoric Remains on the Moors near Kildwick. 'Bradford Scientific Journal,' II. 156-158. 1908.

CLARKE, W. G. Norfolk Neolithic Harpoon-Barbs and Triangular Knives. 'Trans. Norfolk and Norwich Nat. Soc.' VIII. 552-555. 1908.

DORNAN, Rev. S. S. Notes on the Bushmen of Basutoland. 'Trans. S. African Phil. Soc.' XVIII. 437-450. 1909.

FOX, HOWARD. Presidential Address. [Fishermen and Fisheries from the Earliest Times.] 'Journal Royal Inst. Cornwall,' XVII. 184-206. 1908.

GRAY, H. ST. GEORGE. Report on the Wick Barrow Excavations. 'Proc. Somersetshire Arch. N. H. Soc.' LIV. Part II. 1-78. 1909.

—— Excavations at Norton Camp, near Taunton, 1908. 'Proc. Somersetshire Arch. N. H. Soc.' LIV. Part II. 131-143. 1909.

HUNT, Rev. ALFRED. Prehistoric Man in Lincolnshire. (Presidential Address.) 'Trans. Lincolnshire Nat. Union, 1908,' 289-303. 1909.

MEYRICK, E. Anthropometrical Report. 'Report Marlb. Coll. N. H. Soc.' No. 57, 83-110. 1909.

MORTIMER, J. R. Note on a British Burial at Middleton-on-the-Wolds. 'The Naturalist for 1908,' 230-231. 1908.

PÉRINGUEY, L. Rock Engravings of Animals and the Human Figure, found in South Africa. 'Trans. S. African Phil. Soc.' XVIII. 401-419. 1909.

SMITH, JOHN. Torrs Warren. 'Annals Andersonian Nat. Soc.' III. 35-52. 1908.

VILLY, Dr. FRANCIS. An Exploration of Mounds near Cullingworth. 'Bradford Scientific Journal,' II. 219-220. 1909.

WATSON, GEORGE. The Stone Circles of Roxburghshire. 'Trans. Hawick Arch. Soc. 1908,' 20-28. 1908.

WOOD, JOHN M. Notes on a Human Skeleton found at Foxearth, Essex. 'Essex Naturalist,' XV. 164-167. 1908.

Section I.—PHYSIOLOGY.

HALDANE, Dr. J. S. (N. Staff. Inst. Eng.) Diving and Diving Apparatus, with special reference to Diving Work in Mines. 'Trans. Inst. Min. Eng.' XXXV. 298-320. 1908.

JEFFERSON, Dr. ARTHUR. Address. [Modern Medical Practice.] 'Proc. Rochdale Lit. Sci. Soc.' IX. 99-104. 1908.

MCWEENEY, Prof. E. J. Popular Endeavour against Tuberculosis: its Instruments, Methods, and Results. 'Journal Stat. Soc. Ireland,' XII. 62-92. 1908.

MORGAN, Dr. G. Function and Fatigue. (Presidential Address.) 'Report Brighton and Hove N. H. Phil. Soc. 1907-8,' 5-25. 1908.

PLOWRIGHT, Dr. C. B. Six Fatal Cases of Poisoning by *Amanita phalloides* at Ipswich. 'Trans. British Mycological Soc.' III. 25-26. 1908.

Section K.—BOTANY.

ADAMS, J. On the Occurrence of *Allium oleraceum* Linn. in Ireland. 'Irish Naturalist,' XVIII. 111-112. 1909.

ADAMS, JOHN. The New Flora of Burnt Ground on the Hill of Howth: a Story of Plant Dispersal. 'Irish Naturalist,' XVII. 133-134. 1908.

ADAMSON, RICHARD. Our Local Orchids. 'Trans. Vale of Derwent Nat. Field Club,' I. 41-45. 1908.

ALLEN, W. B. *Clavaria conchyliata.* 'Trans. British Mycological Soc.' III. 92. 1909.

—— Fungi, 1907. 'Trans. Caradoc and Severn Valley F. C.' IV. 199-200. 1909.

BAKER, J. G. New Plant Localities from North-East Yorkshire. 'The Naturalist for 1908,' 370. 1908.

—— Euphrasias of North-East Yorkshire. 'The Naturalist for 1909,' 79. 1909.

BENNETT, A. The Halifax Potamogeton. 'The Naturalist for 1908,' 373-375. 1908.

BENNETT, ARTHUR. Distribution of *Veronica verna*, L., *V. triphyllos*, L., *Herniaria glabra*, L., and *Scleranthus perennis*, L. 'Trans. Norfolk and Norwich Nat. Soc.' VIII. 528-534. 1908.

BIFFEN, Prof. R. H. First Record of Two Species of Laboulbeniceæ for Britain. 'Trans. British Mycological Soc.' III. 83. 1909.

BOUDIER, EM. Note sur une nouvelle espèce de Pseudophacidium. 'Trans. British Mycological Soc.' III. 81. 1909.

BOYD, JOHN. The Last of the Pollok Wych Elms. 'Annals Andersonian Nat. Soc.' III. 127-135. 1908.

BRITISH MYCOLOGICAL SOCIETY. The Newcastle-upon-Tyne Foray and complete List of Fungi and Mycetozoa gathered. 'Trans. British Mycological Soc.' III. 9-17. 1908.

—— Report of the Drumnadrochit Foray [Sept. 14-19, 1908], and complete List of Fungi and Mycetozoa gathered. 'Trans. British Mycological Soc.' III. 47-60. 1909.

BURRELL, W. H. Note on a form of *Leucobryum glaucum* Schp. 'Trans. Norfolk and Norwich Nat. Soc.' VIII. 537-539. 1908.

CARADOC AND SEVERN VALLEY FIELD CLUB. Botanical Notes, 1908. 'Record of Bare Facts,' No. 18, 5-16. 1909.

CARR, Prof. J. W. *Selinum carvifolia* Linn. in Nottinghamshire. 'Report Nottingham Nat. Soc. for 1907-8,' 28-29. 1909.

CARROTHERS, N. Report of Botanical Section. 'Report Belfast Nat. F. C.' VI. 10-12. 1908.

CHEETHAM, C. A. Mosses, &c., at Horton-in-Ribblesdale. 'The Naturalist for 1908,' 201-202. 1908.

—— Yorkshire Mosses. 'The Naturalist for 1909,' 144-145. 1909.

CLARKE, W. G. Some Breckland Characteristics. 'Trans. Norfolk and Norwich Nat. Soc.' VIII. 555-578. 1908.

COOKE, M. C. Review of Comments on 'Illustrations of British Fungi,' Transactions, 1906, p. 150. 'Trans. British Mycological Soc.' III. 26-29. 1908.

—— Fungus Notes for 1907. 'Trans. British Mycological Soc.' III. 34. 1908.

—— What is *Hygrophorus Clarkii* Berk. and Br.? 'Trans. British Mycological Soc.' III. 83-85. 1909.

—— Fungus Notes for 1908. 'Trans. British Mycological Soc.' III. 109-110. 1909.

COTTON, A. D. Further Notes on British Clavariæ. 'Trans. British Mycological Soc.' III. 29-33. 1908.

—— Notes on Marine Pyrenomycetes. 'Trans. British Mycological Soc.' III. 92-99. 1909.

CROSSLAND, CHARLES. Omitted Asci Measurements of some British Discomycetes. 'Trans. British Mycological Soc.' III. 85-91. 1909.

—— Recently discovered Fungi in Yorkshire. 'The Naturalist for 1908,' 214-218. 1908.

—— *Hypocrea riccioides* (Bolt.) Berk. [*Sphæria riccioides* Bolton] in Westmorland. 'The Naturalist for 1908,' 371-372. 1908.

—— The Fungus Flora of Mulgrave Woods. 'The Naturalist for 1909,' 21-27. 1909.

—— Recently discovered Fungi in Yorkshire. 'The Naturalist for 1909,' 178-182. 1909.

CRUMP, W. B. Some Halifax Brambles. 'The Naturalist for 1908,' 199-200. 1908.

CRYER, JOHN. Hawkweeds. 'The Naturalist for 1909,' 143-144. 1909.

DAVEY, F. HAMILTON. Additions to the Flora of Cornwall. 'Journal Royal Inst. Cornwall,' XVII. 241-245. 1908.

DAVIES, J. H. Bryological Notes from Down and Louth. 'Irish Naturalist,' XVIII. 12-14. 1909.

DIXON, H. N. Garrick's Mulberry Tree, with Notes on the Planting in Abingdon Park. 'Journal Northants N. H. Soc.' XIV. 251-254. 1908.

—— New Records of Northamptonshire Plants. 'Journal Northants N. H. Soc.' XIV. 257-258. 1908.

DRUCE, G. CLARIDGE. The Oxford British Plant List. 'The Naturalist for 1909,' 97-99. 1909.

—— Botanologia of Northamptonshire. 'Journal Northants N. H. Soc.' XIV. 250-272, 1908; 293-324, 1909.

DUDLEY, ARTHUR H. The Nucleus in Plant Cells. (Presidential Address.) 'Report Liverpool Mic. Soc.' XL. 8-26. 1909.

FERNALD, Prof. M. L. Notes on *Potamogeton pensylvanicus* Cham. 'The Naturalist for 1908,' 375-376. 1908.

FRASER, Miss H. C. I. Recent Work on the Reproduction of Ascomycetes. 'Trans. British Mycological Soc.' III. 100-107. 1909.

FRENCH, JOHN. On Plant Distribution in the Neighbourhood of Felstead. 'Essex Naturalist,' XV. 152-163. 1908.

GIBBS, T. *Bovistella paludosa* Lév., a Puffball new to Britain. 'The Naturalist for 1908,' 457. 1908.

GOLDING, JOHN. Presidential Address. [Adaptation.] 'Report Nottingham Nat. Soc. for 1907-8,' 21-27. 1909.

HEATH, J. W. How Plants fight their Enemies. 'Trans. Caradoc and Severn Valley F. C.' IV. 248-253. 1909.

HILTON, T. Additions to the Herbarium. 'Report Brighton and Hove N. H. Phil. Soc., 1907-8,' 67-68. 1908.

HORWOOD, A. R. The Extinction of Cryptogamic Plants in Ireland. 'Irish Naturalist,' XVII. 151-156. 1908.

JOHNSTONE, MARY A. Equisetales. Horsetails and their Allies. 'Bradford Scientific Journal,' II. 129-135. 1908.

JOHNSTONE, R. B. Clydesdale Fungi. 'Annals Andersonian Nat. Soc.' III. 53-62. 1908.

KAYE, W. J. Orchids and their Cultivation. 'Proc. South London Ent. N. H. Soc. 1908-9,' 16-29. 1909.

KEEGAN, Dr. P. Q. The Sycamore. 'The Naturalist for 1909,' 101-105. 1909.

KNOWLES, Miss M. C., and R. D. O'BRIEN. A Botanical Tour in the Islands of the Fergus Estuary and adjacent Mainland. 'Irish Naturalist,' XVIII. 57-68. 1909.

LANDSBOROUGH, Rev. DAVID. A Campbeltown Palm-lily (*Cordyline australis*). 'Trans. Glasgow N. H. Soc.' VIII. 60-62. 1908.

LEE, JOHN R. The Flora of the Arrochar Mountains. 'Annals Andersonian Nat. Soc.' III. 80-126. 1908.

LEE, P. FOX. *Juncus acutus* L. in North-East Yorkshire. 'The Naturalist for 1908,' 422. 1908.

LEES, F. ARNOLD. A Trio of British and Alien Plant Lists. 'The Naturalist for 1908,' 311-319, 337-344. 1908.

—— Note on *Juncus acutus* L. 'The Naturalist for 1908,' 423. 1908.

—— Note on the Oxford British Plant List. 'The Naturalist for 1909,' 99-100. 1909.

LINTON, Rev. E. F. Notes on the Dorset Flora. 'Proc. Dorset N. H. A. F. C.' XXIX. 14-29. 1908.

LONG, FREDERICK. The Salt-Marsh Flora of Wells. 'Trans. Norfolk and Norwich Nat. Soc.' VIII. 523-527. 1908.

M'ANDREW, JAMES. Two Rare Plants. 'Trans. Edinburgh Field Nat. Mic. Soc.' VI. 66-67. 1908.

MCDONALD, JAMES E. The Dog's Mercury. 'The Naturalist for 1908,' 262-271. 1908.

—— The Broad-leaved Wood Garlic or Ransoms. 'The Naturalist for 1909,' 199-202. 1909.

MACDONALD, J. J. List of British Ferns of the Comrie District. 'Trans. Edinburgh Field Nat. Mic. Soc.' VI. 19. 1908.

MARGERISON, SAMUEL. The Vegetation of some Disused Quarries. 'Bradford Scientific Journal,' II. 141-147, 161-168, 206-214, 235-245. 1908, 1909.

MASEFIELD, J. R. B. Staffordshire Ferns. 'Trans. N. Staffs. F. C.' XLIII. 102-107. 1909.

MASSEE, G. Economic Mycology. 'The Naturalist for 1909,' 28-29. 1909.

MELVILL, J. COSMO. Carl Linnæus. 'Trans. Caradoc and Severn Valley F. C.' IV. 205-216. 1909.

MERLIN, A. A. C. ELIOT. Note on *Navicula Smithii* and *N. crabro*. 'Journal Quekett Mic. Club,' x. 247-250. 1908.

MEYRICK, E. Occurrence of an *Epilobium* new to Britain. 'Report Marlb. Coll. N. H. Soc.' No. 57, 30-31. 1909.

—— Report of the Botanical Section. 'Report Marlb. Coll. N. H. Soc.' No. 57, 35-44. 1909.

Nicholson, W. A. Proposal for a Botanical Survey of the Broads District. 'Trans. Norfolk and Norwich Nat. Soc.' viii. 618-621. 1908.
Painter, W. H. Botanical Report: Phænogams. 'Trans. Caradoc and Severn Valley F. C.' iv. 198-199. 1909.
Petch, T. A. The Bleeding-Stem Disease of the Cocoanut Tree in Ceylon. 'Trans. British Mycological Soc.' iii. 108-109. 1909.
Potter, Prof. M. C. Fungus Foray in Gibside. 'Trans. Vale of Derwent Nat. Field Club,' i. 36-40. 1908.
Praeger, R. Lloyd. Botanical Notes, chiefly from Lough Mask and Kilkee. 'Irish Naturalist,' xviii. 32-40. 1909.
—— On some Irish Hawkweed and Pondweed Records. 'Irish Naturalist,' xviii. 81-85. 1909.
—— The British Vegetation Committee in the West of Ireland. 'The Naturalist for 1908,' 412-416. 1908.
Rea, Carleton. Visit of the British Mycological Society to Gibside, and List of the Fungi and Mycetozoa found there. 'Trans. Vale of Derwent Nat. Field Club,' i. 33-35. 1908.
—— Some Remarks on Basidia and Spores and the Classification suggested by their Study. (Presidential Address.) 'Trans. British Mycological Soc.' iii. 60-80. 1909.
—— New and Rare British Fungi. 'Trans. British Mycological Soc.' iii. 124-130. 1909.
Richardson, Nelson M. Report on First Appearance of Birds, Insects, &c., and First Flowering of Plants in Dorset during 1907. 'Proc. Dorset N. H. A. F. C.' xxix. 281-292. 1908.
Ridge, W. T. Boydon. Botanical Reports. 'Trans. N. Staffs. F. C.' xlii. 85-88, 1908; xliii. 98-101, 1909.
Riley, L. A. M. Some Notes on the Coast Flora of North Cornwall. 'Journal Royal Inst. Cornwall,' xvii. 248-254. 1908.
Robinson, Wilfrid. The Biology of the Propagative Buds of *Malaxis paludosa*. 'The Naturalist for 1908,' 367-369. 1908.
S[heppard], T. On the Fringe of the Cleveland Hills. 'The Naturalist for 1908,' 403-411. 1908.
Smith, Miss Annie Lorrain. Presidential Address. Microfungi: a Historical Sketch. 'Trans. British Mycological Soc.' iii. 28-25. 1908.
—— *Myxobacteriaceæ*. 'Trans. British Mycological Soc.' iii. 82. 1909.
—— New or Rare Microfungi. 'Trans. British Mycological Soc.' iii. 111-124. 1909.
—— and Carleton Rea. New and Rare British Fungi. 'Trans. British Mycological Soc.' iii. 34-36. 1908.
Smith, Dr. W. G. Introduction to the Study of Grasses. 'Bradford Scientific Journal,' ii. 225-231. 1909.
—— and T. H. Taylor. Note on the Lombardy Poplar (*Populus pyramidalis*, Roz.). 'The Naturalist for 1908,' 232-234. 1908.
Snelgrove, E. Peloria in Plants. 'The Naturalist for 1909,' 132-133. 1909.
Somerville, Alex. Note on the Occurrence of *Saxifraga oppositifolia*, L., the Purple Mountain Saxifrage, on the Sea-coast of Islay. 'Trans. Glasgow N. H. Soc.' viii. 71-73. 1908.
Spanton, W. D. Annual Address: The Influence of Plant-life on Art. 'Trans. N. Staffordshire F. C.' xlii. 42-57. 1908.
Spencer, B. Plant Lore. III. Medicine. 'Bradford Scientific Journal,' ii. 153-155. 1908.
Spitta, E. J. The Photography of very Translucent Diatoms at High Magnifications. (Presidential Address.) 'Journal Quekett Mic. Club,' x. 243-246. 1908.
Tomlinson, W. J. C. Local Botanical Field-work in 1907. 'Proc. Belfast Nat. F. C.' vi. 56-61. 1908.

Towers, Miss L. The Distribution of Living Plants in relation to the different Geological Formations in Dorset. 'Proc. Dorset N. H. A. F. C.' xxix. 119-125. 1908.

Trow, Dr. A. H. The Flora of Glamorgan. 'Trans. Cardiff Nat. Soc.' Special Supplement, 1-78. 1908.

—— (Editor.) The Flora of Glamorgan. Section III. *Corolliflorœ.* 'Trans. Cardiff Nat. Soc.' App. 79-132. 1909.

West, Wm. and G. S. The Phytoplankton of the English Lake District. 'The Naturalist for 1909,' 115-122, 132-141, 186-193. 1909.

White, James W. Report of the Botanical Section. 'Proc. Bristol Nat. Soc.' ii. 44-47. 1908.

Winter, W. P. October in the Botanical Garden. 'Bradford Scientific Journal,' ii. 168-170. 1908.

Woodhead, Dr. T. W. Plant Geography and Ecology in Switzerland (*continued*). 'The Naturalist for 1908,' 203-213. 1908.

Woodruffe-Peacock, Rev. E. A. The Rock-Soil Method and *Ballota nigra* Linn. in Lincolnshire. 'The Naturalist for 1909,' 39-44. 1909.

Obituary.

Bailey, Matthew. By R. 'The Naturalist for 1908,' 455-456. 1908.

Brown, Martin Walton. By H. F. Bulman. 'Trans. Inst. Min. Eng.' xxxv. 203-209. 1908.

Evans, Sir John. By T. S[heppard]. 'The Naturalist for 1908,' 242-244. 1908.

Harrison, W. Jerome. By T. S[heppard]. 'The Naturalist for 1908,' 345-349. 1908.

Hart, Henry Chichester. By R. M. Barrington. 'Irish Naturalist,' xvii. 249-254. 1908.

Hudleston, Wilfred H. By T. S[heppard]. 'The Naturalist for 1909,' 123-124. 1909.

Ingram, Dr. John Keels. By C. Litton Falkiner. 'Journal Stat. Soc. Ireland,' xii. 1-124. 1908.

Kelvin, Lord. By Prof. Magnus Maclean. 'Proc. Glasgow R. Phil. Soc.' xxxix. 60-72. 1908.

Kinahan, George Henry. By R. Clark. 'Irish Naturalist,' xviii. 29-31. 1909.

Lawrence, Henry. By John H. Merivale. 'Trans. Inst. Min. Eng.' xxxvii. 121-123. 1909.

Lister, Arthur. 'Bradford Scientific Journal,' ii. 204-205. 1909.

Lomas, Joseph. By Dr. A. R. Dwerryhouse. 'The Naturalist for 1909,' 58-60. 1909.

—— By Professor Percy F. Kendall. 'Proc. Yorkshire Geol. Soc.' xvi. 251-252. 1909.

Mathew, Rev. Murray A. By C. T[ite]. 'Proc. Somersetshire Arch. N. H. Soc.' liv. Part II. 164. 1909.

Newton, Prof. Alfred, and Howard Saunders. By T. Southwell. 'Trans. Norfolk and Norwich Nat. Soc.' viii. 517-523. 1908.

Smith, Reginald Bosworth. By Rev. J. H. Wilkinson. 'Proc. Dorset N. H. A. F. C.' xxix. cxx.-cxxiv. 1908.

Sorby, Henry Clifton. By Professor Percy F. Kendall. 'Proc. Yorkshire Geol. Soc.' xvi. 247-250. 1909.

Spruce, Richard. By T. S[heppard]. 'The Naturalist for 1909,' 45-48. 1909.

Ward, John. By John T. Stobbs (N. Staff. Inst. Eng.). 'Trans. Inst. Min. Eng.' xxxv. 121-132. 1908.

Wardle, Sir Thomas. 'Trans. N. Staffs F. C.' xliii. 60-65. 1909.

TRANSACTIONS OF THE SECTIONS.

TRANSACTIONS OF THE SECTIONS.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section.—Professor E. Rutherford, M.A., D.Sc., F.R.S.

THURSDAY, AUGUST 26.

The President delivered the following Address:—

It is a great privilege and pleasure to address the members of this Section on the occasion of the visit of the British Association to a country with which I have had such a long and pleasant connection. I feel myself in the presence of old friends, for the greater part of what may be called my scientific life has been spent in Canada, and I owe much to this country for the unusual facilities and opportunity for research so liberally provided by one of her great Universities. Canada may well regard with pride her Universities, which have made such liberal provision for teaching and research in pure and applied science. As a physicist, I may be allowed to refer in particular to the subject with which I am most intimately connected. After seeing the splendid home for physical science recently erected by the University of Toronto, and the older but no less serviceable and admirably equipped laboratories of McGill University, one cannot but feel that Canada has recognised in a striking manner the great value attaching to teaching and research in physical science. In this, as in other branches of knowledge, Canada has made notable contributions in the past, and we may confidently anticipate that this is but an earnest of what will be accomplished in the future.

It is my intention to-day to say a few words upon the present position of the atomic theory in physical science, and to discuss briefly the various methods that have been devised to determine the values of certain fundamental atomic magnitudes. The present time seems very opportune for this purpose, for the rapid advance of physics during the last decade has not only given us a much clearer conception of the relation between electricity and matter and of the constitution of the atom, but has provided us with experimental methods of attack undreamt of a few years ago. At a time when, in the vision of the physicist, the atmosphere is dim with flying fragments of atoms, it may not be out of place to see how it has fared with the atoms themselves, and to look carefully at the atomic foundations on which the great superstructure of modern science has been raised. Every physicist and chemist cannot but be aware of the great part the atomic hypothesis plays in science to-day. The idea that matter consists of a great number of small discrete particles forms practically the basis of the explanation of all properties of matter. As an indication of the importance of this theory in the advance of science it is of interest to read

over the Reports of this Association and to note how many addresses, either wholly or in part, have been devoted to a consideration of this subject. Amongst numerous examples I may instance the famous and oft-quoted lecture of Maxwell on Molecules, at Bradford in 1873; the discussion of the Kinetic Theory of Gases by Lord Kelvin, then Sir William Thomson, in Montreal in 1884; and the Presidential Address of Sir Arthur Rücker in 1901, which will be recalled by many here to-day.

It is far from my intention to discuss, except with extreme brevity, the gradual rise and development of the atomic theory. From the point of view of modern science, the atomic theory dates from the work of Dalton about 1805, who put it forward as an explanation of the combination of elements in definite proportions. The simplicity of this explanation of the facts of chemistry led to the rapid adoption of the atomic theory as a very convenient and valuable working hypothesis. By the labour of the chemists matter was shown to be composed of a number of elementary substances which could not be further decomposed by laboratory agencies, and the relative weights of the atoms of the elements were determined. On the physical side, the mathematical development of the kinetic or dynamical theory of gases by the labours of Clausius and Clerk Maxwell enormously extended the utility of this conception. It was shown that the properties of gases could be satisfactorily explained on the assumption that a gas consisted of a great assemblage of minute particles or molecules in continuous agitation, colliding with each other and with the walls of the containing vessel. Between encounters the molecules travelled in straight lines, and the free path of the molecules between collisions was supposed to be large compared with the linear dimensions of the molecules themselves. One cannot but regard with admiration the remarkable success of this statistical theory in explaining the general properties of gases and even predicting unexpected relations. The strength and at the same time the limitations of the theory lie in the fact that it does not involve any definite conception of the nature of the molecules themselves or of the forces acting between them. The molecule, for example, may be considered as a perfectly elastic sphere or a Boscovitch centre of force, as Lord Kelvin preferred to regard it, and yet on suitable assumptions the gas would show the same general statistical properties. We are consequently unable, without the aid of special subsidiary hypotheses, to draw conclusions of value in regard to the nature of the molecules themselves.

Towards the close of the last century the ideas of the atomic theory had impregnated a very large part of the domain of physics and chemistry. The conception of atoms became more and more concrete. The atom in imagination was endowed with size and shape, and unconsciously in many cases with colour. The simplicity and utility of atomic conceptions in explaining the most diverse phenomena of physics and chemistry naturally tended to enhance the importance of the theory in the eyes of the scientific worker. There was a tendency to regard the atomic theory as one of the established facts of nature, and not as a useful working hypothesis for which it was exceedingly difficult to obtain direct and convincing evidence. There were not wanting scientific men and philosophers to point out the uncertain foundations of the theory on which so much depended. Granting how useful molecular ideas were for the explanation of experimental facts, what evidence was there that the atoms were realities and not the figments of the imagination? It must be confessed that this lack of direct evidence did not in any way detract from the strength of the belief of the great majority of scientific men in the discreteness of matter. It was not unnatural, however, that there should be a reaction in some quarters against the domination of the atomic theory in physics and in chemistry. A school of thought arose that wished to do away with the atomic theory as the basis of explanation of chemistry, and substitute as its equivalent the law

of combination in definite proportions. This movement was assisted by the possibility of explaining many chemical facts on the basis of thermo-dynamics without the aid of any hypothesis as to the particular structure of matter. Everyone recognises the great importance of such general methods of explanation, but the trouble is that few can think, or at any rate think correctly, in terms of thermo-dynamics. The negation of the atomic theory has not, and does not, help us to make new discoveries. The great advantage of the atomic theory is that it provides, so to speak, a tangible and concrete idea of matter which serves at once for the explanation of a multitude of facts and is of enormous aid as a working hypothesis. For the great majority of scientists it is not sufficient to group together a number of facts on general abstract principles. What is wanted is a concrete idea, however crude it may be, of the mechanism of the phenomena. This may be a weakness of the scientific mind, but it is one that deserves our sympathetic consideration. It represents an attitude of mind that appeals, I think, very strongly to the Anglo-Saxon temperament. It has no doubt as its basis the underlying idea that the facts of nature are ultimately explicable on general dynamical principles, and that there must consequently be some type of mechanism capable of accounting for the observed facts.

It has been generally considered that a decisive proof of the atomic structure of matter was in the nature of things impossible, and that the atomic theory must of necessity remain an hypothesis unverifiable by direct methods. Recent investigations have, however, disclosed such new and powerful methods of attack that we may well ask the question whether we do not now possess more decisive evidence of its truth.

Since molecules are invisible, it might appear, for example, an impossible hope that an experiment could be devised to show that the molecules of a fluid are in that state of continuous agitation which the kinetic theory leads us to suppose. In this connection I should like to draw your attention for a short time to a most striking phenomenon known as the 'Brownian movement,' which has been closely studied in recent years. Quite apart from its probable explanation the phenomenon is of unusual interest. In 1827 the English botanist Brown observed by means of a microscope that minute particles like spores of plants introduced into a fluid were always in a state of continuous irregular agitation, dancing to and fro in all directions at considerable speeds. For a long time this effect, known as the Brownian movement, was ascribed to inequalities in the temperature of the solution. This was disproved by a number of subsequent investigations, and especially by those of Gouy, who showed that the movement was spontaneous and continuous and was exhibited by very small particles of whatever kind when immersed in a fluid medium. The velocity of agitation increased with decrease of diameter of the particles and increased with temperature, and was dependent on the viscosity of the surrounding fluid. With the advent of the ultra-microscope it has been possible to follow the movements with more certainty and to experiment with much smaller particles. Exner and Zsigmondy have determined the mean velocity of particles of known diameter in various solutions, while Svedberg has devised an ingenious method of determining the mean free path and the average velocity of particles of different diameter. The experiments of Ehrenhaft in 1907 showed that the Brownian movement was not confined to liquids, but was exhibited far more markedly by small particles suspended in gases. By passing an arc discharge between silver poles he produced a fine dust of silver in the air. When examined by means of the ultra-microscope the suspended particles exhibited the characteristic Brownian movement, with the difference that the mean free path for particles of the same size was much greater in gases than in liquids.

The particles exhibit in general the character of the motion which the

kinetic theory ascribes to the molecules themselves, although even the smallest particles examined have a mass which is undoubtedly very large compared with that of the molecule. The character of the Brownian movement irresistibly impresses the observer with the idea that the particles are hurled hither and thither by the action of forces resident in the solution, and that these can only arise from the continuous and ceaseless movement of the invisible molecules of which the fluid is composed. Smoluchowski and Einstein have suggested explanations which are based on the kinetic theory, and there is a fair agreement between calculation and experiment. Strong additional confirmation of this view has been supplied by the very recent experiments of Perrin (1909). He obtained an emulsion of gamboge in water which consisted of a great number of spherical particles nearly of the same size, which showed the characteristic Brownian movement. The particles settled under gravity and when equilibrium was set up the distribution of these particles in layers at different heights was determined by counting the particles with a microscope. The number was found to diminish from the bottom of the vessel upwards according to an exponential law—*i.e.*, according to the same law as the pressure of the atmosphere diminishes from the surface of the earth. In this case, however, on account of the great mass of the particles, their distribution was confined to a region only a fraction of a millimetre deep. In a particular experiment the number of particles per unit volume decreased to half in a distance of 0·038 millimetre, while the corresponding distance in our atmosphere is about 6000 metres. From measurements of the diameter and weight of each particle, Perrin found that, within the limit of experimental error, the law of distribution with height indicated that each small particle had the same average kinetic energy of movement as the molecules of the solutions in which they were suspended; in fact, the particles in suspension behaved in all respects like molecules of very high molecular weight. This is a very important result, for it indicates that the law of equipartition of energy among molecules of different masses, which is an important deduction from the kinetic theory, holds, at any rate very approximately, for a distribution of particles in a medium whose masses and dimensions are exceedingly large compared with that of the molecules of the medium. Whatever may prove to be the exact explanation of this phenomenon, there can be little doubt that it results from the movement of the molecules of the solution and is thus a striking if somewhat indirect proof of the general correctness of the kinetic theory of matter.

From recent work in radioactivity we may take a second illustration which is novel and far more direct. It is well known that the α rays of radium are deflected by both magnetic and electric fields. It may be concluded from this evidence that the radiation is corpuscular in character, consisting of a stream of positively charged particles projected from the radium at a very high velocity. From the measurements of the deflection of the rays in passing through magnetic and electric fields the ratio e/m of the charge carried by the particle to its mass has been determined, and the magnitude of this quantity indicates that the particle is of atomic dimensions.

Rutherford and Geiger have recently developed a direct method of showing that this radiation is, as the other evidence indicated, discontinuous, and that it is possible to detect by a special electric method the passage of a single α particle into a suitable detecting vessel. The entrance of an α particle through a small opening was marked by a sudden movement of the needle of the electrometer which was used as a measuring instrument. In this way, by counting the number of separate impulses communicated to the electrometer needle, it was possible to determine by direct counting the number of α particles expelled per second from one gram

of radium. But we can go further and confirm the result by counting the number of a particles by an entirely distinct method. Sir William Crookes has shown that when the a rays are allowed to fall upon a screen of phosphorescent zinc sulphide, a number of brilliant scintillations are observed. It appears as if the impact of each a particle produced a visible flash of light where it struck the screen. Using suitable screens the number of scintillations per second on a given area can be counted by means of a microscope. It has been shown that the number of scintillations determined in this way is equal to the number of impinging a particles when counted by the electric method. This shows that the impact of each a particle on the zinc sulphide produces a visible scintillation. There are thus two distinct methods—one electrical, the other optical—for detecting the emission of a single a particle from radium. The next question to consider is the nature of the a particle itself. The general evidence indicates that the a particle is a charged atom of helium, and this conclusion was decisively verified by Rutherford and Royds by showing that helium appeared in an exhausted space into which the a particles were fired. The helium, which is produced by radium, is due to the accumulated a particles which are so continuously expelled from it. If the rate of production of helium from radium is measured, we thus have a means of determining directly how many a particles are required to form a given volume of helium gas. This rate of production has recently been measured accurately by Sir James Dewar. He has informed me that his final measurements show that one gram of radium in radioactive equilibrium produces 0·46 cubic millimetres of helium per day, or $5{\cdot}32 \times 10^{-6}$ cubic millimetres per second. Now from the direct counting experiments it is known that $13{\cdot}6 \times 10^{10}$ a particles are shot out per second from one gram of radium in equilibrium. Consequently it requires $2{\cdot}56 \times 10^{19}$ a particles to form one cubic centimetre of helium gas at standard pressure and temperature.

From other lines of evidence it is known that all the a particles from whatever source are identical in mass and constitution. It is not then unreasonable to suppose that the a particle, which exists as a separate entity in its flight, can exist also as a separate entity when the a particles are collected together to form a measurable volume of helium gas, or, in other words, that the a particle on losing its charge becomes the fundamental unit or atom of helium. In the case of a monatomic gas like helium, where the atom and molecule are believed to be identical, no difficulty of deduction arises from the possible combination of two or more atoms to form a complex molecule.

We consequently conclude from these experiments that one cubic centimetre of helium at standard pressure and temperature contains $2{\cdot}56 \times 10^{19}$ atoms. Knowing the density of helium, it at once follows that each atom of helium has a mass of $6{\cdot}8 \times 10^{-24}$ grams, and that the average distance apart of the molecules in the gaseous state at standard pressure and temperatures is $3{\cdot}4 \times 10^{-7}$ centimetres.

The above result can be confirmed in a different way. It is known that the value of e/m for the a particle is 5,070 electromagnetic units. The positive charge carried by each a particle has been deduced by measuring the total charge carried by a counted number of a particles. Its value is $9{\cdot}3 \times 10^{-10}$ electrostatic units, or $3{\cdot}1 \times 10^{-20}$ electromagnetic units. Substituting this number in the value of e/m, it is seen that m, the mass of the a particle, is equal to $6{\cdot}1 \times 10^{-24}$ grams—a value in fair agreement with the number previously given.

I trust that my judgment is not prejudiced by the fact that I have taken some share in these investigations; but the experiments, taken as a whole, appear to me to give an almost direct and convincing proof of the atomic hypothesis of matter. By direct counting, the number of identical entities

required to form a known volume of gas has been measured. May we not conclude that the gas is discrete in structure, and that this number represents the actual number of atoms in the gas?

We have seen that under special conditions it is possible to detect easily by an electrical method the emission of a single α particle—*i.e.*, of a single charged atom of matter. This has been rendered possible by the great velocity and energy of the expelled α particle, which confers on it the power of dissociating or ionising the gas through which it passes. It is obviously only possible to detect the presence of a single atom of matter when it is endowed with some special property or properties which distinguishes it from the molecules of the gas with which it is surrounded. There is a very important and striking method, for example, of visibly differentiating between the ordinary molecules of a gas and the ions produced in the gas by various agencies. C. T. R. Wilson showed in 1897 that under certain conditions each charged ion became a centre of condensation of water vapour, so that the presence of each ion was rendered visible to the eye. Sir Joseph Thomson, H. A. Wilson, and others have employed this method to count the number of ions present and to determine the magnitude of the electric charge carried by each.

A few examples will now be given which illustrate the older methods of estimating the mass and dimensions of molecules. As soon as the idea of the discrete structure of matter had taken firm hold, it was natural that attempts should be made to estimate the degree of coarse-grainedness of matter, and to form an idea of the dimension of molecules, assuming that they have extension in space. Lord Rayleigh has drawn attention to the fact that the earliest estimate of this kind was made by Thomas Young in 1805, from considerations of the theory of capillarity. Space does not allow me to consider the great variety of methods that have later been employed to form an idea of the thickness of a film of matter in which a molecular structure is discernible. This phase of the subject was always a favourite one with Lord Kelvin, who developed a number of important methods of estimating the probable dimensions of molecular structure.

The development of the kinetic theory of gases on a mathematical basis at once suggested methods of estimating the number of molecules in a cubic centimetre of any gas at normal pressure and temperature. This number, which will throughout be denoted by the symbol N, is a fundamental constant of gases; for, according to the hypothesis of Avogadro, and also on the kinetic theory, all gases at normal pressure and temperature have an identical number of molecules in unit volume. Knowing the value of N, approximate estimates can be made of the diameter of the molecule; but in our ignorance of the constitution of the molecule, the meaning of the term diameter is somewhat indefinite. It is usually considered to refer to the diameter of the sphere of action of the forces surrounding the molecule. This diameter is not necessarily the same for the molecules of all gases, so that it is preferable to consider the magnitude of the fundamental constant N. The earliest estimates based on the kinetic theory were made by Loschmidt, Johnstone Stoney, and Maxwell. From the data then at his disposal, the latter found N to be $1{\cdot}9 \times 10^{19}$. Meyer, in his 'Kinetic Theory of Gases,' discusses the various methods of estimating the dimensions of molecules on the theory, and concludes that the most probable estimate of N is $6{\cdot}1 \times 10^{19}$. Estimates of N based on the kinetic theory are only approximate, and in many cases serve merely to fix an inferior or superior limit to the number of the molecules. Such estimates are, however, of considerable interest and historical importance, since for a long time they served as the most reliable methods of forming an idea of molecular magnitudes.

A very interesting and impressive method of determining the value of N was given by Lord Rayleigh in 1899 as a deduction from his theory

of the blue colour in the cloudless sky. This theory supposes that the molecules of the air scatter the waves of light incident upon them. This scattering for particles, small compared with the wave length of light, is proportional to the fourth power of the wave length, so that the proportion of scattered to incident light is much greater for the violet than for the red end of the spectrum, and consequently the sky which is viewed by the scattered light is of a deep blue colour. This scattering of the light in passing through the atmosphere causes alterations of brightness of stars when viewed at different altitudes, and determinations of this loss of brightness have been made experimentally. Knowing this value, the number N of molecules in unit volume can be deduced by aid of the theory. From the data thus available, Lord Rayleigh concluded that the value of N was not less than 7×10^{18}. Lord Kelvin in 1902 recalculated the value of N on the theory by using more recent and more accurate data, and found it to be $2{\cdot}47 \times 10^{19}$. Since in the simple theory no account is taken of the additional scattering due to fine suspended particles which are undoubtedly present in the atmosphere, this method only serves to fix an inferior limit to the value of N. It is difficult to estimate with accuracy the correction to be applied for this effect, but it will be seen that the uncorrected number deduced by Lord Kelvin is not much smaller than the most probable value $2{\cdot}77 \times 10^{19}$ given later. Assuming the correctness of the theory and data employed, this would indicate that the scattering due to suspended particles in the atmosphere is only a small portion of the total scattering due to molecules of air. This is an interesting example of how an accurate knowledge of the value of N may possibly assist in forming an estimate of unknown magnitudes.

It is now necessary to consider some of the more recent and direct methods of estimating N which are based on recent additions to our scientific knowledge. The newer methods allow us to fix the value of N with much more certainty and precision than was possible a few years ago.

We have referred earlier in the paper to the investigations of Perrin on the law of distribution in a fluid of a great number of minute granules, and his proof that the granules behave like molecules of high molecular weight. The value of N can be deduced at once from the experimental results, and is found to be $3{\cdot}14 \times 10^{19}$. The method developed by Perrin is a very novel and ingenious one, and is of great importance in throwing light on the law of equipartition of energy. This new method of attack of fundamental problems will no doubt be much further developed in the future.

It has already been shown that the value $N = 2{\cdot}56 \times 10^{19}$ has been obtained by the direct method of counting the α particles and determining the corresponding volume of helium produced. Another very simple method of determining N from radioactive data is based on the rate of transformation of radium. Boltwood has shown by direct experiment that radium is half transformed in 2,000 years. From this it follows that initially in a gram of radium ·346 milligram breaks up per year. Now it is known from the counting method that $3{\cdot}4 \times 10^{10}$ α particles are expelled per second from one gram of radium, and the evidence indicates that one α particle accompanies the disintegration of each atom. Consequently the number of α particles expelled per year is a measure of the number of atoms of radium present in ·346 milligram. From this it follows that there are $3{\cdot}1 \times 10^{21}$ atoms in one gram of radium, and taking the atomic weight of radium as 226, it is simply deduced that the value of N is $3{\cdot}1 \times 10^{19}$.

The study of the properties of ionised gases in recent years has led to the development of a number of important methods of determining the charge carried by the ion, produced in gases by α rays or the rays from radioactive substances. On modern views, electricity, like matter, is supposed to be discrete in structure, and the charge carried by the hydrogen atom set free by the electrolysis of water is taken as the fundamental unit

of quantity of electricity. On this view, which is supported by strong evidence, the charge carried by the hydrogen atom is the smallest unit of electricity that can be obtained, and every quantity of electricity consists of an integral multiple of this unit. The experiments of Townsend have shown that the charge carried by a gaseous ion is, in the majority of cases, the same and equal in magnitude to the charge carried by a hydrogen atom in the electrolysis of water. From measurement of the quantity of electricity required to set free one gram of hydrogen in electrolysis, it can be deduced that $Ne=1{\cdot}29\times10^{10}$ electrostatic units where N, as before, is the number of molecules of hydrogen in one cubic centimetre of gas, and e the charge carried by each ion. If e be determined experimentally, the value of N can at once be deduced from this relation.

The first direct measurement of the charge carried by the ion was made by Townsend in 1897. When a solution of sulphuric acid is electrolysed, the liberated oxygen is found in a moist atmosphere to give rise to a dense cloud composed of minute globules of water. Each of these minute drops carries a negative charge of electricity. The size of the globules, and consequently the weight, was deduced with the aid of Stokes' formula by observing the rate of fall of the cloud under gravity. The weight of the cloud was measured, and, knowing the weight of each globule, the total number of drops present was determined. Since the total charge carried by the cloud was measured, the charge e carried by each drop was deduced. The value of e, the charge carried by each drop, was found by this method to be about $3{\cdot}0\times10^{-10}$ electrostatic units. The corresponding value of N is about $4{\cdot}3\times10^{19}$.

We have already referred to the method discovered by C. T. R. Wilson of rendering each ion visible by the condensation of water upon it by a sudden expansion of the gas. The property was utilised by Sir Joseph Thomson to measure the charge e carried by each ion. When the expansion of the gas exceeds a certain value, the water condenses on both the negative and positive ions, and a dense cloud of small water drops is seen. J. J. Thomson found $e=3{\cdot}4\times10^{-10}$, H. A. Wilson $e=3{\cdot}1\times10^{-10}$, and Millikan and Begeman $4{\cdot}06\times10^{-10}$. The corresponding values of N are 3·8, 4·2, and $3{\cdot}2\times10^{19}$ respectively. This method is of great interest and importance, as it provides a method of directly counting the number of ions produced in the gas. An exact determination of e by this method is, however, unfortunately beset with great experimental difficulties.

Moreau has recently measured the charge carried by the negative ions produced in flames. The values deduced for e and N were respectively $4{\cdot}3\times10^{-10}$ and $3{\cdot}0\times10^{19}$.

We have referred earlier in the paper to the work of Ehrenhaft on the Brownian movement in air shown by ultra-microscopic dust of silver. In a recent paper (1909) he has shown that each of these particles carries a positive or negative charge. The size of each particle was measured by the ultra-microscope, and also by the rate of fall under gravity. The charge carried by each particle was deduced from the measured mass of the particle, and its rate of movement in an electric field. The mean value of e was found to be $4{\cdot}6\times10^{-10}$, and thus N becomes $2{\cdot}74\times10^{19}$.

A third important method of determination of N from radioactive data was given by Rutherford and Geiger in 1908. The charge carried by each α particle expelled from radium was measured by directly determining the total charge carried by a counted number of α particles. The value of the charge on each α particle was found to be $9{\cdot}3\times10^{-10}$. From consideration of the general evidence, it was concluded that each α particle carries two unit positive charges, so that the value of e becomes $4{\cdot}65\times10^{-10}$, and of N $2{\cdot}77\times10^{19}$. This method is deserving of considerable confidence as the measurements involved are direct and capable of accuracy.

The methods of determination of e, so far explained, have depended on

direct experiment. This discussion would not be complete without a reference to an important determination of e from theoretical considerations by Planck. From the theory of the distribution of energy in the spectrum of a hot body, Planck found that $e=4{\cdot}69\times10^{-10}$, and $N=2{\cdot}80\times10^{19}$. For reasons that we cannot enter into here, this theoretical deduction must be given great weight.

When we consider the great diversity of the theories and methods which have been utilised to determine the values of the atomic constants e and N, and the probable experimental errors, the agreement among the numbers is remarkably close. This is especially the case in considering the more recent measurements by very different methods, which are far more reliable than the older estimates. It is difficult to fix on one determination as more deserving of confidence than another; but I may be pardoned if I place some reliance on the radioactive method previously discussed, which depends on the charge carried by the a particle. The value obtained in this way is not only in close agreement with the theoretical estimate of Planck, but is in fair agreement with the recent determinations by several other distinct methods. We may consequently conclude that the number of molecules in a cubic centimetre of any gas at standard pressure and temperature is about $2{\cdot}77\times10^{19}$, and that the value of the fundamental unit of quantity of electricity is about $4{\cdot}65\times10^{-10}$ electrostatic units. From these data it is a simple matter to deduce the mass of any atom whose atomic weight is known, and to determine the values of a number of related atomic and molecular magnitudes.

There is now no reason to view the values of these fundamental constants with scepticism, but they may be employed with confidence in calculations to advance still further our knowledge of the constitution of atoms and molecules. There will no doubt be a great number of investigations in the future to fix the values of these important constants with the greatest possible precision; but there is every reason to believe that the values are already known with reasonable certainty, and with a degree of accuracy far greater than it was possible to attain a few years ago. The remarkable agreement in the values of e and N, based on so many different theories, of itself affords exceedingly strong evidence of the correctness of the atomic theory of matter, and of electricity, for it is difficult to believe that such concordance would show itself if the atoms and their charges had no real existence.

There has been a tendency in some quarters to suppose that the development of physics in recent years has cast doubt on the validity of the atomic theory of matter. This view is quite erroneous, for it will be clear from the evidence already discussed that the recent discoveries have not only greatly strengthened the evidence in support of the theory, but have given an almost direct and convincing proof of its correctness. The chemical atom as a definite unit in the subdivision of matter is now fixed in an impregnable position in science. Leaving out of account considerations of etymology, the atom in chemistry has long been considered to refer only to the smallest unit of matter that enters into ordinary chemical combination. There is no assumption made that the atom itself is indestructible and eternal, or that methods may not ultimately be found for its subdivision into still more elementary units. The advent of the electron has shown that the atom is not the unit of smallest mass of which we have cognisance, while the study of radioactive bodies has shown that the atoms of a few elements of high atomic weight are not permanently stable, but break up spontaneously with the appearance of new types of matter. These advances in knowledge do not in any way invalidate the position of the chemical atom, but rather indicate its great importance as a subdivision of matter whose properties should be exhaustively studied.

The proof of the existence of corpuscles or electrons with an apparent

mass very small compared with that of the hydrogen atom, marks an important stage in the extension of our ideas of atomic constitution. This discovery, which has exercised a profound influence on the development of modern physics, we owe mainly to the genius of the President of this Association. The existence of the electron as a distinct entity is established by similar methods and with almost the same certainty as the existence of individual α particles. While it has not yet been found possible to detect a single electron by its electrical or optical effect, and thus to count the number directly as in the case of the α particles, there seems to be no reason why this should not be accomplished by the electric method. The effect to be anticipated for a single β particle is much smaller than that due to an α particle, but not too small for measurement. In this connection it is of interest to note that Regener has observed evidence of scintillations produced by the β particles of radium falling on a screen of platinocyanide of barium, but the scintillations are too feeble to count with certainty.

Experiment has shown that the apparent mass of the electron varies with its speed, and, by comparison of theory with experiment, it has been concluded that the mass of the electron is entirely electrical in origin and that there is no necessity to assume a material nucleus on which the electrical charge is distributed. While there can be no doubt that electrons can be released from the atom or molecule by a variety of agencies and, when in rapid motion, can retain an independent existence, there is still much room for discussion as to the actual constitution of electrons, if such a term may be employed, and of the part they play in atomic structure. There can be little doubt that the atom is a complex system, consisting of a number of positively and negatively charged masses which are held in equilibrium mainly by electrical forces; but it is difficult to assign the relative importance of the *rôle* played by the carriers of positive and negative electricity. While negative electricity can exist as a separate entity in the electron, there is yet no decisive proof of the existence of a corresponding positive electron. It is not known how much of the mass of an atom is due to electrons or other moving charges, or whether a type of mass quite distinct from electrical mass exists. Advance in this direction must be delayed until a clearer knowledge is gained of the character and structure of positive electricity and of its relation to the negative electron.

The general experimental evidence indicates that electrons play two distinct *rôles* in the structure of the atom, one as lightly attached and easily removable satellites or outliers of the atomic system, and the other as integral constituents of the interior structure of the atom. The former, which can be easily detached or set in vibration, probably play an important part in the combination of atoms to form molecules, and in the spectra of the elements; the latter, which are held in place by much stronger forces, can only be released as a result of an atomic explosion involving the disintegration of the atom. For example, the release of an electron with slow velocity by ordinary laboratory agencies does not appear to endanger the stability of the atom, but the expulsion of a high speed electron from a radioactive substance accompanies the transformation of the atom.

The idea that the atoms of the elements may be complex structures, made up either of lighter atoms or of the atoms of some fundamental substance, has long been familiar to science. So far no direct evidence has been obtained of the possibility of building up an atom of higher atomic weight from one of lower atomic weight, but in the case of the radioactive substances we have decisive and definite evidence that certain elements show the converse process of disintegration. It may be significant that this process has only been observed in the atoms of highest atomic weights, like those of uranium, thorium, and radium. With the exception possibly

of potassium, there is no reliable evidence that a similar process takes place in other elements. The transformation of the atom of a radioactive substance appears to result from an atomic explosion of great intensity in which a part of the atom is expelled with great speed. In the majority of cases, an α particle or atom of helium is ejected, in some cases a high-speed electron, while a few substances are transformed without the appearance of a detectable radiation. The fact that the α particles from a simple substance are all ejected with an identical and very high velocity suggests the probability that the charged helium atom before its expulsion is in rapid orbital movement in the atom. There is at present no definite evidence of the causes operative in these atomic transformations.

Since in a large number of cases the transformations of the atoms are accompanied by the expulsion of one or more charged atoms of helium, it is difficult to avoid the conclusion that the atoms of the radioactive elements are built up, in part at least, of helium atoms. It is certainly very remarkable and may prove of great significance, that helium, which is regarded from the ordinary chemical standpoint as an inert element, plays such an important part in the constitution of the atoms of uranium, thorium, and radium.

The study of radioactivity has not only thrown great light on the character of atomic transformations, but it has also led to the development of methods for detecting the presence of almost infinitesimal quantities of radioactive matter. It has already been pointed out that two methods—one electrical, the other optical—have been devised for the detection of a single α particle. By the use of the optical or scintillation method, it is possible to count with accuracy the number of α particles when only one is expelled per minute. It is not a difficult matter, consequently, to follow the transformation of any radioactive substance in which only one atom breaks up per minute, provided that an α particle accompanies the transformation. In the case of a rapidly changing substance like the actinium emanation, which has a half period of 3·7 seconds, it is possible to detect with certainty the presence, if not of a single atom, at any rate of a few atoms, while the presence of a hundred atoms would in some cases give an inconveniently large effect. The counting of the scintillations affords an exceedingly powerful and direct quantitative method of studying the properties of radioactive substances which expel α particles. Not only is it a simple matter to count the number of α particles which are expelled in any given interval, but it is possible, for example, by suitably arranged experiments to decide whether one, two or more α particles are expelled at the disintegration of a single atom.

The possibility of detection of a single atom of matter has opened up a new field of investigation in the study of discontinuous phenomena. For example, the experimental law of transformation of radioactive matter expresses only the average rate of transformation, but by the aid of the scintillation or electric method it is possible to determine directly by experiment the actual interval between the disintegration of successive atoms and the probability law of distribution of the α particles about the average value.

Quite apart from the importance of studying radioactive changes, the radiations from active bodies provide very valuable information as to the effects produced by high velocity particles in traversing matter. The three types of radiation, the α, β, and γ rays, emitted from active bodies, differ widely in character and their power of penetration of matter. The α particles, for example, are completely stopped by a sheet of notepaper, while the γ rays from radium can be easily detected after traversing twenty centimetres of lead. The differences in the character of the absorption of the radiations are no doubt partly due to the difference in type of the radiation and partly due to the differences of velocity.

The character of the effects produced by the α and β particles is most simply studied in gases. The α particle has such great energy of motion that it plunges through the molecules of the gas in its path, and leaves in its train more than a hundred thousand ionised or dissociated molecules. After traversing a certain distance, the α particle suddenly loses its characteristic properties and vanishes from the ken of our observational methods. It no doubt quickly loses its high velocity, and after its charge has been neutralised becomes a wandering atom of helium. The ionisation produced by the α particle appears to consist of the liberation of one or more slow velocity electrons from the molecule, but in the case of complex gases there is no doubt that the act of ionisation is accompanied by a chemical dissociation of the molecule itself, although it is difficult to decide whether this dissociation is a primary or secondary effect. The chemical dissociation produced by α particles opens up a wide field of investigation, on which, so far, only a beginning has been made.

The β particle differs from the α particle in its much greater power of penetration of matter, and the very small number of molecules it ionises compared with the α particle traversing the same path in the gas. It is very easily deflected from its path by encounters with the gas molecules, and there is strong evidence that, unlike the α particle, the β particle can be stopped or entrapped by a molecule when travelling at a very high speed.

When the great energy of motion of the α particle and the small amount of energy absorbed in ionising a single molecule are taken into consideration, there appears to be no doubt that the α particle, as Bragg pointed out, actually passes through the atom, or rather the sphere of action of the atom which lies in its path. There is, so to speak, no time for the atom to get out of the way of the swiftly moving α particle, but the latter must pass through the atomic system. On this view, the old dictum, no doubt true in most cases, that two bodies cannot occupy the same space, no longer holds for atoms of matter if moving at a sufficiently high speed.

There would appear to be little doubt that a careful study of the effects produced by the α or β particle in passing through matter will ultimately throw much further light on the constitution of the atom itself. Work already done shows that the character of the absorption of the radiations is intimately connected with the atomic weights of the elements and their position in the periodic table. One of the most striking effects of the passage of β rays through matter is the scattering of the β particles, *i.e.*, the deflection from their rectilinear path by their encounters with the molecules. It was for some time thought that such a scattering could not be expected to occur in the case of the α particles in consequence of their much greater mass and energy of motion. The recent experiments of Geiger, however, show that the scattering of the α particles is very marked, and is so great that a small fraction of the α particles, which impinge on a screen of metal, have their velocity reversed in direction and emerge again on the same side. This scattering can be most conveniently studied by the method of scintillations. It can be shown that the deflection of the α particle from its path is quite perceptible after passing through very few atoms of matter. The conclusion is unavoidable that the atom is the seat of an intense electric field, for otherwise it would be impossible to change the direction of the particle in passing over such a minute distance as the diameter of a molecule.

In conclusion, I should like to emphasise the simplicity and directness of the methods of attack on atomic problems opened up by recent discoveries. As we have seen, not only is it a simple matter, for example, to count the number of α particles by the scintillations produced on a zinc sulphide screen, but it is possible to examine directly the deflection of an individual

particle in passing through a magnetic or electric field, and to determine the deviation of each particle from a rectilinear path due to encounters with molecules of matter. We can determine directly the mass of each α particle, its charge, and its velocity, and can deduce at once the number of atoms present in a given weight of any known kind of matter. In the light of these and similar direct deductions, based on a minimum amount of assumption, the physicists have, I think, some justification for their faith that they are building on the solid rock of fact, and not, as we are often so solemnly warned by some of our scientific brethren, on the shifting sands of imaginative hypothesis.

The following Papers were read:—

1. *Preliminary Note on the Pressure of Radiation against the Source. The Recoil from Light. By* Professor J. H. Poynting, *F.R.S., and* Guy Barlow, *D.Sc.*

All previous experiments on the pressure of radiation have been made on the force exerted by the radiation on a receiving surface. In the experiment described the pressure against the source from which the radiation starts is shown to exist. The effect may be termed the recoil from light.

If an exceedingly thin disc, with both surfaces perfectly black, could be suspended in a perfect vacuum, a beam of energy P per c.c. directed normally on to it would exert pressure P when the temperature of the disc reached a steady state. For the energy absorbed at the front surface would, with a sufficiently thin disc, be emitted equally from front and back, and the resulting pressures of the issuing radiation would be equal and opposite, leaving only the pressure P of the incident beam. If the front surface were perfectly black and the back surface were perfectly reflecting and non-radiating, all the energy absorbed would be emitted from the front surface. As it would be emitted according to the cosine law the pressure due to it would be $\frac{2}{3}$ P, and the total pressure would be $\frac{5}{3}$ P.

The experiment consisted in approximating to these conditions as nearly as possible. A globe was evacuated to as high a degree as could be attained, and in it was suspended by a quartz fibre a system of four discs, each 1·2 cm. diameter, and at an arm 1 cm. Each disc consisted of two cover-glasses, with a thin layer of asphaltum between. For a reflecting surface the outer surface of the glass was silvered by cathode deposition. The four discs were respectively black-black, black-silver, silver-silver, and silver-black on their front and back surfaces. A beam was directed on to the front surfaces of each of these in turn. The measurement of its energy per c.c. showed that on a perfectly black surface it should give 14·2 divisions deflection of the scale used. On the actual discs it gave respectively 16·3, 22·5, 29·8, and 27·2 divisions—means of several determinations. The black surface was not a full absorber, partly through the reflection from the front glass. A small amount of radiometer action still remained, and both of these conditions tended to increase the pressure on it. The silver was not a perfect reflector, and so the second effect was slightly reduced. With perfectly black and perfectly reflecting surfaces the deflections should have been 14·2, 23·7, 28·4, and 28·4 divisions respectively. The observed results are sufficiently near to these to show that the increased effect on the second surface was chiefly due to the recoil from the radiation issuing from it as source.

---

2. *Some Properties of Light of very Short Wave-Lengths. By* Professor Theodore Lyman.—See Reports, p. 132.

---

3. *The Lowell Observatory Photographs of Jupiter.* *By* Professor PERCIVAL LOWELL.

The new system of planetary photography devised and carried out at the Lowell Observatory has secured the detailed images of Jupiter here presented. Its difficulty as compared with celestial photography in general will be realised on considering that in the finest star photographs the whole disc of a planet would be a mere point.

The present results have been got chiefly through the ability of one of the staff, Mr. C. O. Lampland, though other members have contributed. The undertaking necessitated the utmost definition at every step of the process. Among the factors to this end were:—

1. Selection of the observatory site for steady air.
2. The remarkable unification of focus of all parts of the glass, the 24-inch Clark refractor, due to Mr. Lundin.
3. The securing of a particular colour-screen.
4. Particular isochromatic plates.
5. Suitable development.
6. Guiding by hand.
7. Adjustment of size of image and exposure time; for Jupiter this time was $3\frac{1}{2}$-4 seconds.

Results.—The images disclose a surprising delicacy of detail. Specially noteworthy are the faint wisps that crisscross like lacings the several belts, particularly the bright equatorial one. Some of these can be seen in the drawings of Sir William Huggins, fifty years ago, and their complete character was detected by Mr. Scriven Bolton. The small white spots which are so peculiar a feature of the disc also come out in the images. Transits of the satellites and of their shadows are stamped there, sometimes more than one upon a single plate.

The great number of images taken consecutively on each plate serves to part defects in the film or specks on the colour-screen from details on the planet.

Deductions.—1. Measurement of the images shows that, after allowance is made for the planet's axial tilt, the bright equatorial belt lies exactly upon the planet's equator. Thus the clouds which clearly compose it are Jove-raised, not sun-raised, ones.

2. Measurement of the dark belts show that they occupy approximately the position of the spot zones on the sun.

3. The photographs show that the edge of the disc is less luminous than the centre, as is also known visually. The same is true of the sun.

4. The dark belts are a cherry-red. This hue is also vouched for by their spectrum, which, taken by another member of the staff, Dr. V. M. Slipher, side by side with that of the bright belt, discloses a greater general absorption in the blue-green.

5. Spectrograms by the same show the special Jovian absorption bands J_2 J_3 more intense, for equal general illumination, in the bright equatorial belt. This does not seem true of J_1.

6. Müller's, the latest determination of Jupiter's albedo, is 75 per cent.; that of cloud, 72 per cent. This raises a presumption that Jupiter shines partly by inherent light. The margin, however, is too small to permit of certain deductions—at present.

7. The belts and wisps are best explained as gaps in the clouds formed by condensing of uprising vapours from Jupiter's heated interior and strung out by his rotation. The planet is still a semi-sun.

---

4. *Early Drawings of Jupiter.* By Sir WILLIAM HUGGINS, *F.R.S.*

---

5. *On the Motion of some of the Small Stars in Messier 92 (Herculis). By* Professor E. E. Barnard.

The visual and photographic measures of the great globular star clusters show that very little measurable motion exists in any of the small stars composing them.

In two cases in the cluster Messier 92 (Herculis) motion is certain. Following are the positions of these stars:—

Star 1 (No. 11 of Schultz's list):

1902·0 α 17^{h} 14^{m} $3^{s}\cdot75$ $\delta = +43°$ 12′ 12″·9. Mag. 13·2.

Visual measures (seven years' interval):

Centennial motion 8″·3 in the direction 225°·3.

Photographic measures (eight years' interval):

Centennial motion 8″·5 in the direction 222°·0.

The second star is much fainter:—

1902·0 α 17^{h} 14^{m} $9^{s}\cdot58$ $\delta + 43°$ 14′ 50″4. Mag. $14\frac{1}{2}$.

Centennial motion from the photographs (eight years' interval):

6″·5 in the direction 181°·4.

The first star is moving away from the centre of the cluster; the second one is moving towards the centre.

There are several other faint stars of this cluster that seem to have a slight motion.

These results show us that many of the stars in this cluster will doubtless develop motion in fifty years' time, and that in a few hundred years we shall be able to investigate the motions that control these great and dense masses of stars.

FRIDAY, AUGUST 27.

Department of Mathematics.

The following Papers and Report were read:—

1. *Theorems in General Analysis. By* Professor E. H. Moore, *Ph.D., LL.D., Sc.D.*

Especially during the last decade the study of Integral Equations has brought to light numerous fundamental *analogies* between the n-fold algebra of real n-dimensional space and the theory of continuous functions of an argument varying over a finite interval of the real number system and the theory of certain types of functions of infinitely many variables.

We lay down a fundamental principle of generalisation by abstraction: *The existence of analogies between central features of various theories implies the existence of a general theory which underlies the particular theories and unifies them with respect to those central features.* The form of General Analysis in question, designed to furnish such a general theory of Integral Equations, is apt to play a central rôle in the comparative or organic development of various analytic doctrines.

We consider analytic systems Σ of the type $(\mathfrak{A}; \mathfrak{P}; \mathfrak{M})$. Here $\mathfrak{A}$ denotes the real number system, and $\mathfrak{P}$ denotes a class $[p]$ of elements p, while $\mathfrak{M}$ denotes a class $[\mu]$ of real-valued single-valued functions μ of the variable element p of

the class $\mathfrak{P}$. Fundamentally important instances of such systems are the following:—

I) $\mathfrak{P}^{\mathrm{I}}$ is the class of a single element p. $\mathfrak{M}^{\mathrm{I}}$ is the class of all functions μ of p—*i.e.* $\mathfrak{M}^{\mathrm{I}}$ is the real number system $\mathfrak{A}$.

II$_n$) $\mathfrak{P}^{\mathrm{II}}{}_n$ is the class of n elements p. $\mathfrak{M}^{\mathrm{II}}{}_n$ is the class of all functions μ of p—*i.e.* $\mathfrak{M}^{\mathrm{II}}{}_n$ is the class of all n-partite real numbers.

III) $\mathfrak{P}^{\mathrm{III}}$ is the denumerable infinitude of elements $p=1, 2, 3, \ldots, n, \ldots$ $\mathfrak{M}^{\mathrm{III}}$ is the class of all functions μ of p for which the corresponding series, $\Sigma\mu(p)$, is absolutely convergent.

IV) $\mathfrak{P}^{\mathrm{IV}}$ is the linear interval: $0 \leq p \leq 1$, of the real number system. $\mathfrak{M}^{\mathrm{IV}}$ is the class of all continuous functions μ of p.

Properties of systems Σ common to the systems $\Sigma^{\mathrm{I}}, \ldots, \Sigma^{\mathrm{IV}}$ are of fundamental importance. Such properties of Σ are essentially properties of $\mathfrak{M}$, since properties (*e.g.* convergence, continuity) of individual functions μ have usually reference to special features (*e.g.* denumerability, possession of the operation $-$ and of the relation $<$) of the class $\mathfrak{P}$, the range of the variable p. Thus, there are the closure properties: the absolute value of a function of $\mathfrak{M}$, or the product by a constant of a function of $\mathfrak{M}$, or the sum or the product of two functions of $\mathfrak{M}$ is in every case a function of $\mathfrak{M}$. For $\mathfrak{M}=\mathfrak{M}^{\mathrm{IV}}$ there is furthermore the closure property that the limit of a uniformly convergent sequence of functions of $\mathfrak{M}$ is a function of $\mathfrak{M}$. This is not a property of $\mathfrak{M}=\mathfrak{M}^{\mathrm{III}}$. However, if we generalise uniform convergence to convergence uniform relative to a function taken as scale of convergence, replacing the ϵ entering the final inequality of the definition of uniform convergence by ϵ multiplied by the absolute value of the scale function, we secure a corresponding common property of the classes $\mathfrak{M}^{\mathrm{I}}, \ldots \mathfrak{M}^{\mathrm{IV}}$, viz., the class $\mathfrak{M}$ contains the limit of every sequence of functions of $\mathfrak{M}$ which converges uniformly relatively to some function of $\mathfrak{M}$. There is further the dominance property D, that for every sequence of functions of $\mathfrak{M}$ there exists a function of $\mathfrak{M}$ such that every function of the sequence is dominated by some numerical multiple of the function.

A memoir, entitled 'Introduction to a Form of General Analysis,' will appear shortly in a volume to be published by the Yale University Press. In the first part of this memoir I consider, especially with respect to these closure and dominance properties, the inter-relations of classes $\mathfrak{M}$ with a common range $\mathfrak{P}$. In the second part I consider the composition of ranges $\mathfrak{P}$ and of classes $\mathfrak{M}$, obtaining, by the introduction of the notion *development* of a range $\mathfrak{P}$, and allied properties, somewhat akin to convergence and continuity, of classes $\mathfrak{M}$, a very general theorem characterising functionally in terms of suitably conditioned classes $\mathfrak{M}$, $\mathfrak{M}'$ the functions of their $*$-composite class $(\mathfrak{M}\mathfrak{M}')_*$; *e.g.*, for $\mathfrak{M}=\mathfrak{M}^{\mathrm{IV}}$, $\mathfrak{M}'=\mathfrak{M}'^{\mathrm{IV}}$, the $*$-composite class is the class of all functions of the two variables p, p' continuous over the square: $0 \leq p, p' \leq 1$, and these functions are likewise the functions continuous in p' for every p and uniformly continuous in p on $\mathfrak{P}$ uniformly in p' on $\mathfrak{P}'$.

In a paper: 'On a Form of General Analysis with Application to Linear Differential and Integral Equations,'[1] I defined a system as *a system of General Analysis*, and the corresponding theory as *a theory of General Analysis* in case *they involve one or more variables about whose character and range of variation information is given only by the mediation of conditions involving one or more classes of functions of those and perhaps other variables.* In connection with functional transformations of classes $\mathfrak{M}$ into classes $\mathfrak{M}'$ there arises the question of generalising the fundamental existence theorems of Analysis. Indeed, the systematic study of the various analytic doctrines from the point of view of General Analysis will reveal types of properties and theorems of inter-relation of the highest novelty and importance. In a memoir to be presented to the London Mathematical Society I intend to take up in some detail the theory of systems of linear differential equations in General Analysis; the theory outlined in my Rome paper will be much simplified.

---

[1] *Atti del IV Congresso Internationale dei Matematici*, vol. ii. pp. 98–114.

2. *On the present State of the Theory of Aggregates.* *By* Professor E. W. Hobson, *F.R.S.*

Various points which have been raised in the course of recent controversies relating to the abstract theory of aggregates were discussed in some detail. The desirability was pointed out of a new definition of an 'aggregate,' of a more restricted character than the one due to G. Cantor, and of such a character that no difficulties would arise from the ascription of a cardinal number to each such aggregate, and also of an ordinal type in case the aggregate is an ordered one.

---

3. *Generalisation of the Icosahedral Group.* *By* Professor G. A. Miller, *Ph.D.*

The icosahedral group may be completely defined by the fact that its two generating operators (t_1, t_2) satisfy one of the following three sets of conditions:—

$$t_1^2 = t_2^5 = (t_1 t_2)^3 = 1,\ t_1^2 = t_2^3 = (t_1 t_2)^5 = 1,\ t_1^3 = t_2^5 = (t_1 t_2)^2 = 1.$$

Several years ago the author considered the groups which result when these conditions are replaced by somewhat more general ones, as follows:—

$$t_1^2 = t_2^5,\ (t_1 t_2)^3 = 1;\ t_1^2 = t_2^3,\ (t_1 t_2)^5 = 1;\ t_1^3 = t_2^5,\ (t_1 t_2)^2 = 1.$$

He found that each of these three sets of generators leads to only a small number of distinct groups. That is, only a small number of groups can be generated by two operators which satisfy one of these sets of conditions. These results were published in the *Transactions* of the American Mathematical Society. In the present Paper he considers the still more general sets of conditions:—

$$t_1^2 = t_2^5,\ (t_1 t_2)^3 = (t_2 t_1)^3;\ t_1^2 = t_2^3,\ (t_1 t_2)^5 = (t_2 t_1)^5;\ t_1^3 = t_2^5,\ (t_1 t_2)^2 = (t_2 t_1)^2.$$

Among the most important theorems which he established are the following. There is an infinite number of groups, each of which may be generated by two operators satisfying one of these conditions. Each of the possible groups generated by (t_1, t_2) contains either the icosahedral group or the group of Order 120, which is insoluble and does not contain a sub-group of Order 60, and it must have one of these groups for its commutator subgroup.

---

4. *A New Proof of Weierstrass's Theorem.* *By* Professor G. A. Bliss.

The theorem of Weierstrass with which the author dealt is one concerning the factorisation of power series. Any convergent series in $p+1$ variables, $F(x_1, x_2, \ldots, x_p, y)$, in which the lowest term in y alone is of degree n, can be expressed as a product:

$$(y^n + a_1 y^{n-1} + \ldots + a_{n-1} y + a_n)\, \Phi\, (x_1, \ldots, x_p, y),$$

Where $a_1, a_2, \ldots a_n$ are convergent series in $x_1, x_2, \ldots, x_p$, which vanish with these arguments, while Φ is a convergent series in all $p+1$ variables with a constant term different from zero. The theorem is important because it enables one to separate from the function F a polynomial whose roots are the only values of y which can satisfy the equation $F=0$ in the neighbourhood of the origin. The original proof by Weierstrass, and most of the later ones, depend upon function theory. Goursat, however, recently called attention to the essentially elementary character of the theorem, and gave a more direct demonstration. In the present Paper a proof is given which seems still simpler than that of Goursat, and formulæ are set down by means of which the coefficients in the series $a_1, a_2, \ldots, a_n, \Phi$ may be readily computed.

---

5. *On Ideal Numbers.* By J. H. GRACE, *M.A., F.R.S.*

---

6. *On a Correspondence in the Theory of the Partition of Numbers. By* Major P. A. MACMAHON, *F.R.S.*

---

7. *A Continuant of Order N+I which is expressible as the Product of N+I Factors. By* Professor W. H. METZLER, *Ph.D.*

The theorem of this paper may be expressed as follows. The continuant :—

$$\begin{array}{ccccc}
r & a\alpha & 0 & 0 & 0 \\
na(\alpha-\beta) & r-a\beta & 2a\alpha & 0 & 0 \\
0 & (n-1)a(\alpha-\beta) & r-2a\beta & 3a\alpha & 0 \\
0 & 0 & (n-2)a(\alpha-\beta) & r-3a\alpha & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & r-(n-1)a\beta & na\alpha \\
0 & & \cdot & a(\alpha-\beta) & r-na\beta
\end{array}$$

$$=\{r+na(\alpha-\beta)\}\,\{r+na(\alpha-\beta)-2a\alpha+a\beta\}\,\{r+na(\alpha-\beta)-4a\alpha+2a\beta\} \ldots \{r-na\alpha\} \quad (1)$$

It will be observed here that each factor differs from the preceding by the quantity $a\beta-2a\alpha$.

If in this theorem we put $a=\beta=1$ it reduces to

$$\begin{array}{ccccc}
r & \alpha & 0 & 0 & 0 \\
n(\alpha-1) & r-1 & 2\alpha & 0 & 0 \\
0 & (n-1)(\alpha-1) & r-2 & 3\alpha & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot & \cdot \\
0 & \cdot & \cdot & \alpha-1 & r-n
\end{array}$$

$$=\{r+n(\alpha-1)\}\,\{r+n(\alpha-1-2\alpha+1\}\ldots\{r-n\alpha\} \quad (2)$$

a theorem due to Painvin.[1]

If in (1) $\beta=2a$ all the factors become equal to $(r-na\alpha)$, and the theorem becomes

$$\begin{array}{ccccc}
r & a\alpha & 0 & \cdot & 0 \\
-na\alpha & r-2a\alpha & 2a\alpha & \cdot & 0 \\
0 & -(n-1)a\alpha & r-4a\alpha & 3a\alpha & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdot \\
0 & \cdot & \cdot & -a\alpha & r-2na\alpha
\end{array}$$

$$=(r-na\alpha)^{n+1} \quad (3)$$

If in (3) we put $a\alpha=1$ it reduces to a special case of (2) noted by Painvin (*loco citato*).

If in (1) we put $\beta=0$ it reduces to

$$\begin{array}{ccccc}
r & a\alpha & 0 & 0 & 0 \\
na\alpha & r & 2a\alpha & 0 & 0 \\
0 & (n-1)a\alpha & r & 3a\alpha & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdot \\
0 & \cdot & \cdot & r & na\alpha \\
0 & \cdot & \cdot & a\alpha & r
\end{array}$$

$$=(r^2-n^2a^2\alpha^2)(r^2-(n-1)^2a^2\alpha^2)\ldots\ldots\ldots\ldots(r^2-a^2\alpha^2) \quad \text{or}$$
$$=(r^2-n^2a^2\alpha^2)(r^2-(n-1)^2a^2\alpha^2)\ldots\ldots\ldots\ldots(r^2-2^2a^2\alpha^2)r$$

according as n is even or odd, the factors coming together in pairs . . (4)

If in (4) we put $a\alpha=1$ it reduces to a theorem given by Sylvester.[2]

---

[1] *Journ. de Liouville*, iii. [2] *Nouv. Annales de Math.*, xiii.

8. *Imaginary Geometry of the Conic.* *By* Professor ELLERY W. DAVIS, *Ph.D.*

In this paper a complete representation is given of the elements of the central conic whose axes are non-similar complex quantities, making it depend upon the representation of two auxiliary circles having each one of the axes for their radii. The entire plane, with the exception of the interior of a certain fundamental conic, is covered with pairs of conics, each pair connected by vectors that are the representatives of the complex elements.

---

9. *On the Invention of the Slide Rule.* *By* Professor FLORIAN CAJORI.

When and by whom was the slide rule invented? Some say Edmund Gunter, 1620 or 1624; Augustus De Morgan said William Oughtred, 1632; most writers of to-day say Edmund Wingate, 1624, 1626, 1627, or 1630.

De Morgan's claim that Gunter invented 'Gunter's scale,' but not the slide rule, can be verified by consulting Gunter's works, which are easily accessible. No one denies that Oughtred invented the circular and the rectilinear slide rule; that his Latin MS., describing them, was translated by William Forster into English and published in 1632 and 1633. The main question is, Did Wingate invent the rectilinear slide rule, and is he entitled to priority? Hutton, Benoit, Hammer, Favaro, Mehmke, D'Ocagne, Henrici say Yes; De Morgan says No. But De Morgan had not seen all Wingate's works, most of the other writers had not seen any. We have had examined all of Wingate's mathematical works, which had not been seen previously by De Morgan and Benoit. None contain the slide rule, and *Oughtred is the inventor of it.* The following books by Wingate have been examined: *L'usage de la règle de proportion en l'arithmétique et géométrie*, 1624, seen by Benoit, copies in Bodleian Library (Oxford), in Bibliothèque Nationale and Bibliothèque Mazarine (Paris); *Use of the Rule of Proportion*, 1626, 1628, 1645, 1658, 1683, the 1645 edition seen by De Morgan, copy in British Museum; *Arithmétique Logarithmique*, 1626, seen by De Morgan; *Construction and Use of Line of Proportion*, 1628, copy in British Museum; *Of Naturall and Artificiall Arithmetique*, 1630, 1652, copy of 1630 edition in Bodleian, of 1652 edition in British Museum; *Ludus Mathematicus*, 1654, 1681, seen by De Morgan; *Use of the Gauge-rod*, 2nd edition, in Bodleian; *The Clarks Tutor*, 1671, 1676, copies in Bodleian.

---

10. *The Asymptotic Expansions of Legendre Functions.* *By* J. W. NICHOLSON, *M.A.*, *D.Sc.*

The results given in this paper are generalised forms of those relating to Bessel functions.[1] The Legendre functions are defined by the contour integrals, in the plane of a variable t.

$$P_n{}^m(\mu) = \frac{e^{-im\pi}}{4\pi \sin n\pi} \frac{\omega(m+n)}{\omega(n)} (\mu^2-1)^{\frac{1}{2}m} \int^{\mu+,1+,\mu-,1-.} 2^{-n}(t^2-1)^n (t-\mu)^{-n-1}$$

$$Q^n{}_m(\mu) = \frac{e^{-i\pi(n+1)}}{4i \sin n\pi} \frac{\omega(m+n)}{\omega(n)} (\mu^2-1)^{\frac{1}{2}m} \int^{-1+,1-,} 2^{-n}(t^2-1)^n (t-\mu)^{n-m-1}$$

with a cross-cut from $t=1$ to $t=-\infty$.

When m is a positive integer, this definition yields

$$(P_n{}^m, Q_n{}^m)(\mu) = (\mu^2-1)^{\frac{1}{2}m}\, d^m/d\mu^m\, (P_n, Q_n)(\mu)$$

[1] *B.A. Report*, Dublin, 1908.

and in general, the functions admit the following expansions:[1]

(*a*) $P_n^m(\mu)=\dfrac{1}{\omega(-m)}\left(\dfrac{\mu+1}{\mu-1}\right)^{\frac{1}{2}m} F\left(-n, n+1, 1-m, \tfrac{1}{2}(1-\mu)\right) \quad 1-\mu/<2$

(*b*) $Q_n^m(\mu)=$

$$-i.2^{m-1}e^{\frac{1}{2}(m-n)\pi i}\frac{\omega\left(\frac{n+m+1}{2}\right)\omega(-\frac{1}{2})}{\omega\left(\frac{n-m}{2}\right)}(\mu^2-1)^{\frac{1}{2}m}F\left(\frac{n+m+1}{2},\frac{m-n}{2},\frac{1}{2},\mu^2\right)$$

$$+2^m e^{\frac{1}{2}(m-n)\pi i}\frac{\omega\left(\frac{n+m}{2}\right)\omega(-\frac{1}{2})}{\omega\left(\frac{n-m-1}{2}\right)}\mu.(\mu^2-1)^{\frac{1}{2}m}F\left(\frac{m-n+1}{2},\frac{m+n+2}{2},\frac{3}{2},\mu^2\right);$$

where $/\mu/<1$ and μ is positive. If μ be negative, the exponential has argument $\frac{1}{2}(3m+n)\pi i$.

(*c*) If $/\mu/>1$,

$$Q_n^m(\mu)=2^{-n-1}e^{im\pi}\frac{\omega(n+m)\omega(-\frac{1}{2})}{\omega(n+\frac{1}{2})}\frac{(\mu^2-1)^{\frac{1}{2}m}}{\mu^{m+n+1}}F\left(\frac{m+n+2}{2},\frac{m+n+1}{2},n+\frac{3}{2},\frac{1}{\mu^2}\right).$$

(*d*) If $/\mu/>1$,

$$P_n^m(\mu)=\frac{\sin(n+m)\pi}{2^{n+1}\cos n\pi}\frac{\omega(n+m)}{\omega(n+\frac{1}{2})\,\omega(-\frac{1}{2})}\frac{(\mu^2-1)^{\frac{1}{2}m}}{\mu^{m+n+1}}F\left(\frac{n+m+2}{2},\frac{n+m+1}{2},n+\frac{3}{2},\frac{1}{\mu^2}\right)$$
$$+\frac{2^n\omega(n-\frac{1}{2})}{\omega(n-m)\,\omega(-\frac{1}{2})}(\mu^2-1)^{\frac{1}{2}m}\mu^{n-m}F\left(\frac{m-n+1}{2},\frac{m-n}{2},\frac{1}{2}-n,\frac{1}{\mu^2}\right).$$

These define the functions of argument greater than unity. When $/\mu/<1$, $P_n^m(\mu)$ is defined as the common value of $e^{\pm im\pi}P_n^m(\mu\pm 0\,.\,i)$ and

$$2\,e^{im\pi}Q_n^m(\mu)=e^{-\frac{1}{2}im\pi}Q_n^m(\mu+0\,.\,i)+e^{\frac{1}{2}im\pi}Q_n^m(\mu-0\,.\,i).$$

The expansions of the paper, when n is large, are as follows:—

Let $\lambda_1, \lambda_2, \ldots$ be a series of coefficients satisfying

$$k^4(k^2-1)(r-2)(r-4)(r-6)\lambda_{r-6}+k^2(2-3k^2)(r-2)(r-3)(r-4)\lambda_{r-4}$$
$$+(r+2)\{k^2+3k^2(r-2)^2-(r-2)^2\}\lambda_{r-2}+(r-1)\{(2n+1)^2-(n-1)^2\}\lambda_r=0,$$

with $\lambda_1=1,\ \lambda_3=-(4k^2+1)/8((n+\frac{1}{2})^2-1^2),$

$$4^2\{(n+\tfrac{1}{2})^2-2^2\}\lambda_5=-6k^2(2-3k^2)+3(4k^2-1)(28k^2-9)/8\{(n+\tfrac{1}{2})^2-1^2\}$$

where $k=m/(n+\frac{1}{2}),$

so that, if k is not of order greater than unity, $\lambda_3, \lambda_5, \lambda_7$ are of the same order, but λ_9 of order n^2 less, and so for every third coefficient. Moreover, let D denote the operation

$$D\equiv 1+\mu_1\frac{d}{kdk}-\frac{\mu_2}{1}\left(\frac{d}{kdk}\right)^2+\frac{\mu_3}{1\,.\,3}\left(\frac{d}{kdk}\right)^3\ldots$$

where the μ's are given identically by

$$1+\mu_1x+\mu_2x^2+\ \ldots\ \equiv(1+\lambda_3x+\lambda_5x^2+\ \ldots)^{-1},$$

and have the same property of convergence as the λ's.

Then the following expansions exist, for a real argument, n being large:—

Case 1:

$\mu>1$, $m<n+\frac{1}{2}$, the latter not being an integer,

$$P_n^m(\mu)-e^{-im\pi}\frac{\sin(m+n)\pi}{\pi\cos n\pi}Q_n^m(\mu)=\left(\frac{\omega(n+m)}{\pi\omega(n-m)\,.\,\mu^2-1}\right)^{\frac{1}{2}}T^{\frac{1}{2}}e$$

$$Q_n^m(\mu)=e^{im\pi}\left(\frac{\pi\,.\,\omega(n+m)}{\omega(n-m)\,.\,\mu^2-1}\right)^{\frac{1}{2}}T^{\frac{1}{2}}e^{-t}$$

[1] Hobson, *Phil. Trans. Assoc.*, 1896, p. 443 *et seq.*

where $$T = \frac{\mu^2 - 1}{(2n+1)(\mu^2 + k^2 - 1)^{\frac{1}{2}}} \left\{ 1 + \frac{\lambda_3}{\nu^2 + k^2} + \frac{\lambda_5}{(\nu^2 + k^2)^2} \cdots \right\}$$

$$t/n + \tfrac{1}{2} = D \cdot \left\{ \log_e \{\mu + (\nu^2 + k^2)^{\frac{1}{2}}\} - \frac{k}{2} \log \left\{ \frac{(\nu^2 + k^2)^{\frac{1}{2}} + k\mu}{(\nu^2 + k^2)^{\frac{1}{2}} - k\mu} \cdot \frac{1-k}{1+k} \right\} \right.$$

and $\nu^2 = \mu^2 - 1$. This holds even when $m = n + \frac{1}{2}$.

Case 2:

$\mu > 1$, $m > n + \frac{1}{2}$, which is not integral.

The expansion in this case only differs from that of Case 1 in the form of t, which becomes

$$t/n + \tfrac{1}{2} = D \cdot \left\{ \log_e \{\mu + (\nu^2 + k^2)^{\frac{1}{2}}\} - \frac{k}{2} \log \left\{ \frac{k\mu + (\nu^2 + k^2)^{\frac{1}{2}}}{k\mu - (\nu^2 + k^2)^{\frac{1}{2}}} \cdot \frac{k-1}{k+1} \right\} \right..$$

If m and n are both integers, $P_n^m(\mu)$ must be defined with another multiplier, and the expansion is readily obtained.

Case 3:

$$0 < \mu < (1-k^2)^{\frac{1}{2}},\ k < 1.$$

$$P_n^m(\mu) = \frac{2}{\pi^{\frac{1}{2}}} \frac{\omega(n+m)}{\omega(n+\frac{1}{2})} \cdot (2 \cdot 1 - \mu^2)^{-\frac{1}{2}} R^{\frac{1}{2}} \sin \rho,$$

$$Q_n^m(\mu) = \pi^{\frac{1}{2}} \frac{\omega(n+m)}{\omega(n+\frac{1}{2})} \cdot (2 \cdot 1 - \mu^2)^{-\frac{1}{2}} R^{\frac{1}{2}} \cos \rho,$$

where $$R = (1-\mu^2) \left\{ \frac{1}{(1-k^2-\mu^2)^{\frac{1}{2}}} - \frac{\lambda_3}{(1-k^2-\mu^2)^{\frac{3}{2}}} + \frac{\lambda_5}{(1-k^2-\mu^2)^{\frac{5}{2}}} \cdots \right\},$$

$$\rho = (m+n+1)\frac{\pi}{2} + \frac{\omega^2(n+\frac{1}{2})}{\omega(n+m)\omega(n-m)} D' \left(\frac{k \tan^{-1} k\mu}{(1-k^2-\mu^2)^{\frac{1}{2}}} - \sin^{-1} \frac{\mu}{(1-k^2)^{\frac{1}{2}}} \right)$$

where D' is the operation D with the signs of $\mu_1, \mu_3 \ldots$ changed.

Case 4:

$$k > 1,\ \mu < 1,$$

$$P_n^m(\mu) = \frac{2}{\pi^{\frac{1}{2}}} \frac{\omega(n+m)}{\omega(n+\frac{1}{2})} \cdot (2 \cdot 1 - \mu^2)^{-\frac{1}{2}} R^{\frac{1}{2}} \sin \rho,$$

$$Q_n^m(\mu) = \pi^{\frac{1}{2}} \frac{\omega(n+m)}{\omega(n+\frac{1}{2})} (2 \cdot 1 - \mu^2)^{-\frac{1}{2}} R^{\frac{1}{2}} \cos \rho,$$

where $$R = \frac{1-\mu^2}{(k^2+\nu^2)^{\frac{1}{2}}} \left\{ 1 + \frac{\lambda_3}{k^2+\nu^2} + \frac{\lambda_5}{(k^2+\nu^2)^2} \cdots \right\}$$

$$\rho = (m+n+1)\frac{\pi}{2} - \frac{\omega^2(n+\frac{1}{2})}{\omega(n+m)\omega(n-m)} D \cdot \left\{ \frac{k}{2} \log \frac{(k^2+\nu^2)^{\frac{1}{2}} + k\mu}{(k^2+\nu^2)^{\frac{1}{2}} - k\mu} + \tfrac{1}{2} \log (k^2-1) \right.$$
$$\left. - \log \left(\mu + (k^2+\nu^2)^{\frac{1}{2}}\right) \right\}.$$

Case 5:

$$k < 1,\ \mu > (1-k^2)^{\frac{1}{2}}.$$

The expansion is that of Case 3, with a change of ρ to

$$\rho = (m+n+1)\frac{\pi}{2} - \frac{\omega^2(n+\frac{1}{2})}{\omega(n+m)\omega(n-m)} D \left\{ \frac{k}{2} \log_e \cdot \frac{(k^2+\nu^2)^{\frac{1}{2}} + k\mu}{k\mu - (k^2+\nu^2)^{\frac{1}{2}}} + \tfrac{1}{2} \log (1-k^2) \right.$$
$$\left. - \log \mu + (k^2+\nu^2)^{\frac{1}{2}} \right\}.$$

Case 6:

When $\mu < 1 = \cos\theta$, and $\cos\theta = m/n + \frac{1}{2}$ nearly,

$$6\pi^{\frac{1}{2}}3^{-\frac{1}{3}}m^{\frac{1}{3}}(\cos\theta)^{\frac{1}{3}}\,\frac{\pi}{2}\,\mathrm{P}_n^{m^2}(\mu) = \frac{\omega(n+m)}{\omega(n-m)}\left\{\Gamma\left(\frac{1}{6}\right)\sin\frac{\pi}{6} + \rho\Gamma\left(\frac{3}{6}\right)\sin\left(\frac{-\pi}{6}\right) + \frac{\rho^2}{2!}\Gamma\left(\frac{5}{6}\right)\sin\left(\frac{-3\pi}{6}\right) + \ldots\right\},$$

$$6\pi^{\frac{1}{2}}3^{-\frac{1}{3}}m^{\frac{1}{3}}(\cos\theta)^{\frac{1}{3}}\mathrm{Q}_n^m(\mu)\mathrm{P}_n^m(\mu) = -\frac{\omega(n+m)}{\omega(n-m)}\left\{\Gamma\left(\frac{1}{6}\right)\cos\frac{\pi}{6} + \rho\Gamma\left(\frac{3}{6}\right)\cos\left(\frac{-\pi}{6}\right) + \frac{\rho^2}{2!}\Gamma\left(\frac{5}{6}\right)\cos\left(\frac{-3\pi}{6}\right) + \ldots\right\}$$

where $$\rho = 2n+1\,.\left(\frac{3}{m\cos^2\theta}\right)^{\frac{1}{3}}\left(\sin\theta - \frac{2m}{2n+1}\right),$$

and is small.

By the use of the relation

$$\mathrm{J}_m(z) = \mu_{n=\infty}\,\mathrm{P}_n^m\left\{\cos\frac{z}{n}\right\},$$

and its analogue, it may be shown that all the expansions for Bessel functions given in a previous paper are special cases of these.

The toroidal functions, with $n + \frac{1}{2}$ integral, are excluded from the investigation.

11. *Report on Bessel Functions.*—See Reports, p. 33.

Department of General Physics.

The following Papers were read:—

1. *On Threefold Emission-Spectra of Solid Aromatic Compounds. By Professor* E. Goldstein.—See Reports, p. 129.

2. *The Influence of Electrolytes on Colloidal Ferric Oxide Solutions. By* E. F. Burton.

A commercial ferric oxide solution was dialysed in conductivity water, and the velocity with which the particles moved in a unit electric field was observed from time to time. At first, as the solution was purified, the velocity of the particles increased, but as the purification was carried on the velocity gradually decreased in almost linear relation with the amount of chlorine found in the colloidal solution.

The influence of $\frac{\mathrm{N}}{1000}$ potassium phosphate on the velocity of the particles was measured, and was found to be analogous to the action on the Bredig copper colloidal solution previously tried by the author (Phil. Mag., May 1909).

A comparison of the coagulating powers of monovalent, divalent, and trivalent ions on the colloidal particles indicates that the Linder-Picton-Hardy law holds.

3. *Separation of New Radio-active Disintegration Products. By* Dr. Otto Hahn.

The disintegration theory of Rutherford and Soddy has brought forward a long list of radio-active products, which have distinct chemical and physical properties, and which may be separated by various methods.

Some of these products emit α particles, some β particles, some emit

α and β particles, and some do not seem to emit rays at all. The α particles for each special product are emitted with a quite definite speed, which is characteristic for the product. This apparently does not hold true for the β rays. The absorption curves for the β rays are in some cases complex, and seem to indicate complex β rays; in some cases the absorption curves indicate only one type of rays. In collaboration with Dr. Lise Meitner, the author began, two years ago, an investigation of all the various β-ray products, with the view of comparing all the separate and single products under identical conditions. As the result they put forward a working hypothesis that *single radio-active products emit only one type of radiation, either homogeneous α particles or homogeneous β* particles. In the view of this hypothesis all products emitting α and β rays or complex β rays must be complex and be separable into two or more single products. The working hypothesis proved fertile in the case of the active deposits of thorium, actinium, and radium.

The active deposit of thorium consists of four different, single products Th A, B, C, D, thorium D being a new product with a life period of three minutes, emitting the β rays which formerly were attributed to Th C.

The active deposit of actinium consists of three different single products, Act A, B, C, the latter having a period of 5·1 minutes, and emitting the β rays which before had been attributed to Actinium B.

In the case of the quickly decaying active deposit of radium, we have apparently single β rays from radium B, complex ones from radium C; therefore radium C must be complex and consist of three products, one α and two β ray substances. It is, of course, a matter of great difficulty to separate by chemical means very quickly decaying products, and I have therefore made use of the 'recoil method' of separating radio-active disintegration products. The effects in the case of pure radium C were very weak; but this was to be anticipated supposing the α rays to be omitted from the rest product of radium C. The result seems to show that really radium C is complex, consisting, besides the nineteen minutes product, of one substance of about 1-2 minutes' period, and one with an even shorter life.

But there is still a better possibility of proving the correctness of the hypothesis. The authors have found that *radium itself emits β rays of a quite distinct character.*

As it has long been known that radium itself emits also α particles, in the view of the hypothesis radium itself must be complex and consist of two different products, say radium and radium X.

Some recent experiments seem to indicate that this might be the case, and it looks as if radium itself emits easily absorbable β rays only, and the hypothetical substance radium X emits the well-known α particles.

If further work should prove radium to be complex, there is little doubt that the few other radio-active transformation products which still emit complex rays are complex, and therefore may be separated. We might then be in a position to find some relation between life periods and other qualities of the products and the kind and velocity of the rays the products emit.

---

4. *On the Secondary Rays excited in different Metals by Alpha Rays.*
By Professor J. C. McLennan.

In this paper an account was given of experiments which led to the following conclusions:—

I. The secondary rays emitted by a selected metal when bombarded by the alpha rays from polonium deposited on copper are proportional to the intensity of the alpha radiation.

II. The secondary rays excited in thick plates of different metals by alpha rays of constant intensity from polonium were measured by the electrical charge acquired under the emission of the secondary rays by the plates when insulated in high vacua. The following order of intensities was found for the different metals:—

	Intensity of Secondary Rays
Platinum	62·02
Silver	61·08
Zinc	60·76
Lead	59·85
Copper	50·75
Tin	49·48
Aluminium	47·08

III. The delta rays from deposits of polonium on the metals zinc, lead, aluminium, and copper were found to be proportional to the intensities of the alpha radiation from these deposits, *i.e.*, the delta radiation appeared to be independent of the metal which carried the deposit of polonium.

IV. Considerations were presented which support the view that the delta radiation is produced by and accompanies the alpha particle in the course of its expulsion from the polonium atom.

---

5. *On some Phenomena associated with the Radiations from Polonium. By* V. E. Pound, *M.A.*

In this paper experiments were described dealing with the electrical charge acquired by an insulated metal plate B placed close to and facing an insulated copper plate A bearing a deposit of polonium.

A series of curves was submitted which made it clear that, by the use of moderate electric and magnetic fields, at least three types of radiation were present and exerted an effect of greater or less degree on the charge acquired by the plate B, viz. (1), the alpha rays emitted by the plate A; (2) an easily absorbed secondary radiation emitted by the plate B consisting of negatively charged particles; and (3) an easily absorbed delta radiation emitted by the plate A.

With the application of high electric and magnetic fields, however, results were obtained which indicated the existence of a radiation which had hitherto escaped detection, of negatively charged particles from the polonium deposits.

From the behaviour of this radiation under various conditions it was considered to consist of streams of rest-atoms from the active product Radium G or polonium.

---

6. *Anode Rays and their Spectra. By* Dr. Otto Reichenheim.

See Reports, p. 124.

---

7. *On Clark and Weston Standard Cells. By* H. L. Bronson, *Ph.D., and* A. N. Shaw, *B.A.*

This paper dealt mainly with the accuracy and reproducibility of Clark and Weston cells, and it is hoped that it may throw further light on the value of the cell as one of the two legal electrical standards.

The work has been very much facilitated by the courtesy of the Bureau of Standards at Washington, where one of the authors, at the suggestion of Dr. H. T. Barnes, spent some time in the summer vacation of 1908 in studying the construction of modern standard cells. At the invitation of

Dr. F. A. Wolff we have been glad to actively co-operate with the Bureau in the work it has been doing along these lines.

I. *The Reproducibility of the Cells when prepared according to the Specifications of Wolff and Waters.*—The mean of fifteen Clark cells made in this way differed, a few weeks after their construction, from the mean of the reference cells of the Bureau of Standards by less than 14 microvolts. The average deviation of our cells from their own mean was not more than 13, while the maximum deviation was only 31 microvolts.

In the case of the Weston cells the figures were similar, but showed somewhat better agreement in every case; the difference between the mean of thirteen cells and the mean of the reference cells at the Bureau of Standards being in this case 4 microvolts, the average deviation of the cells from their own mean being 8, and the maximum deviation being 22.

Some of the Clark and Weston cells were made in Washington by one of the writers and subsequently transported to Montreal. A means of direct comparison with the values of the cells at the Bureau of Standards was thus obtained. This comparison has recently been checked by a second interchange of cells.

We have also had in our possession six Weston cells made at the National Physical Laboratory in London. One of these was damaged in transit; the mean of the other five differed from the mean of our other cells by only 5 microvolts.

II. *The Effect of Introducing Slight Simplifications into the Preparation of Materials.*—About twenty-five cells were constructed in order to examine the effects of slight simplifications in their preparation. It was found that the ingredient of main importance is the mercurous sulphate, which must always be prepared with great care. When unpurified mercurous sulphate was used in a cell, the average electromotive force was found to be from 300 to 500 microvolts higher than that of the normal cell. The purification of the zinc and cadmium salts is not so important, and as the processes are somewhat tedious, especially in the case of cadmium sulphate, it is interesting to see what accuracy may be obtained with various samples of chemically pure commercial sulphates. It was found that no Clark cell made with this modification differed by more than 50 microvolts from the mean of our normal cells, while no Weston cell differed by more than 100 microvolts. Such cells are therefore sufficiently accurate for all practical work.

The presence of basic oxide, oil, or small quantities of organic impurities was found to exert only a very small influence on the electromotive force.

III. *The Relative Value of Cells set up according to the Board of Trade Specifications and those set up according to the Specifications of Wolff and Waters.*—Ten Clark cells of the old 'test-tube crystal' type were prepared from a number of different samples of chemically pure commercial materials, for the purpose of ascertaining how much they differed in voltage from those set up according to the modern specifications. The average electromotive force of these cells during the first seventy-five days, neglecting the first day, was 0·31 millivolts higher than the mean of our normal cells. The average deviation of these cells from their own mean was considerable, about 0·06 millivolts, which suggests that there might be a possible variation of three or four in the last figure of the mean for different batches of ten cells set up with different materials. It is therefore in good agreement with the value (0·00030 volts) given by Wolff and Waters.

IV. *The Ratio of the Electromotive Force of the Weston Cell to that of the Clark.*—The determination of this ratio, which had also been obtained at the Bureau of Standards, was made with the object of furnishing a further check on the reliability of the comparison between our cells and those of the Bureau, and to give added assurance that no errors had been introduced by transportation.

Five Clark cells were connected in series and placed in opposition to

seven Westons similarly connected. The difference between the two sets was then measured on a Kelvin-Varley slide by the usual potentiometer method.

The ratio obtained was 0·716953, which differs from the ratio 0·716958, determined by Wolff and Waters, by only seven parts in a million. This difference, small as it is, is entirely accounted for by the small differences, as ascertained by direct comparison between our cells and those made at the Bureau of Standards.

---

8. *On the Action of Alpha Rays upon Glass.* *By* Professor E. Rutherford, *F.R.S.*

Department of Cosmical Physics.

The following Papers were read:—

1. *Results of some Recent Terrestrial Magnetic Work.* *By* Dr. L. A. Bauer.

The first slides shown related to the results obtained from the general magnetic survey of the United States, chiefly executed under the author's direction during the period 1899-1906. On the average, the three magnetic elements have been determined, with every possible care, at one station for every 973 square miles; hence the average distance apart between stations is thirty-one miles. The iso-magnetic lines reveal great irregularities, and it has become evident, from a preliminary analysis, that it would not be possible to establish a general formula for the earth which could even approximately represent the actual magnetic conditions observed, unless a prohibitively large number of terms were embraced in the series.

This survey afforded opportunity for a test as to how closely the observed magnetic forces could be referred to a potential, or, in other words, as to the existence of possible vertical electric currents passing from the air into the earth, or *vice versa.* The line integrals were calculated around various closed circuits, one embracing the whole of the United States. The observational quantities could be represented by a potential to within about $\frac{1}{300}$ part, whereas the observational error was about $\frac{1}{500}$ part. Hence there was, apparently, a small outstanding portion that might have to be referred to non-potential forces, such as vertical electric currents.

The question as to the existence of such currents can further be tested by the recent magnetic work in the Pacific Ocean of the Carnegie Institution of Washington, and the calculations are now in progress. Furthermore, by the end of 1910, in view of the work already accomplished and the results to be obtained from the ocean magnetic survey just begun in the Atlantic, it will be possible to make one or two complete circuits of the earth on the basis of freshly acquired data. Views of the vessel *Carnegie*, engaged in the ocean work, were shown, and the methods of observation briefly stated.

Next, brief consideration was paid to various kinds of magnetic disturbances, *e.g.*, the magnetic one associated with the Mont Pélée eruptions of May 8, 1902, and occurring simultaneously over the whole earth, and next the evidently purely mechanical one at the time of the San Francisco earthquake, April 18, 1906. The latter effect was propagated with the speed of the long seismic waves, and was recorded at the Coast and Geodetic magnetic observatories at Honolulu, Sitka, Baldwin (Kansas), and Cheltenham (Maryland). The time of beginning agreed very closely with that given by the seismographs.

In conclusion, a brief *résumé* was given of an investigation on the relation between solar activity and terrestrial magnetic activity conducted

in co-operation with Professor George E. Hale. One of the chief points of interest is the effects on the permanent magnetisation of the earth, which appear to be associated in some manner with changes in solar activity. The magnetic and solar data utilised embrace the period May 1906 to January 1909. It was found that the absolute magnetic effect, connected apparently with an *increase* in solar activity, is equivalent, in general, to a *diminution* in the earth's mean intensity of magnetisation, amounting between the dates February 1, 1907, and February 1, 1908, to about $\frac{1}{1000}$ part. It was shown that for a successful analysis it is necessary to embrace all the magnetic elements and to separate the observed effect into its component parts—that due to the change in the external system of forces and that to be referred to changes in the system of magnetic forces below the earth's surface.

---

2. *The Surface Movement of Air in certain Circular Storms.* *By* J. I. Craig, *M.A., F.R.S.E.*

The paper considered the curve traced by a particle of air which moves in such a way that the tangent to its path always makes a constant angle (α) with the circumference of a moving circle passing through the particle and described about a centre which is moving rectilinearly. The speed of the particle parallel to the circumference ($V\cos\alpha$) bears a given ratio ($1/\lambda$) to the speed of the moving circle (U) so that $U=\lambda V\cos\alpha$. This is an idealised case of ordinary cyclonic movement in nature.

References to previous work were given as follows: *Theoretical*—(1) Dr. W. N. Shaw, F.R.S., 'Q. J. R. Met. S.,' vol. xxix. 1903, p. 233, and 'Monthly Weather Review,' vol. xxxi. 1903, p. 318; (2) Professor W. H. H. Hudson, 'Rep. Brit. Assoc.,' York Meeting, p. 483; (3) Mr. G. T. Bennett, *vide* (4) below, p. 98. *Practical*—(4) Dr. W. N. Shaw, F.R.S., and Mr. R. G. K. Lempfert, 'The Life History of Surface Air-Currents' (London, 1906).

The equation of motion relative to the centre is first studied and found to be

$$\text{when}\quad \lambda<1,\ r(1+\lambda\sin\theta)=a\ \text{exp.}\left[-\frac{2\tan\alpha}{\mu}\tan^{-1}\eta\right]\ \text{where}\ \lambda^2+\mu^2=1,\ \text{and}$$

$$\eta=(\tan\tfrac{1}{2}\theta+\lambda)/\mu$$

$$\text{when}\quad \lambda=1,\ r(1+\sin\theta)=a\ \text{exp.}\ [2\tan\alpha/(1+\tan\tfrac{1}{2}\theta)]$$

$$\text{when}\quad \lambda>1,\ r(1+\lambda\sin\theta)=a[(1+\tan\tfrac{1}{2}\beta\tan\tfrac{1}{2}\theta)/(1+\cot\tfrac{1}{2}\beta\tan\tfrac{1}{2}\theta)]^{\tan\alpha\tan\beta}$$

$$\text{where}\qquad \operatorname{cosec}\beta=\lambda.$$

The particular case studied by Mr. Bennett, when there is no incurvature, is easily derived by putting $\alpha=0$. The curve is then given by the equation $r(1+\lambda\sin\theta)=a$ and is an hyperbola, a parabola or an ellipse according as λ is $>$ = or <1.

Some particular examples exhibiting the general properties of the curves have been computed for values of λ from 3 to 1/3, and of α from 0 to 45°, which include most of the cases of interest in practice.

A difference may be noted between the trajectories when $\lambda\ngtr1$, and when $\lambda>1$. In the first case all the trajectories finish in the centre, with the exception of the limiting case where there is no incurvature. In the second case some trajectories with small incurvature do not finish in the centre, while if the incurvature is increased the resulting trajectories do so finish. These classes are separated by a parabolic trajectory.

The trajectories observed in practice by Dr. Shaw and Mr. Lempfert were then compared with those deduced theoretically, and found to be in satisfactory agreement with them.

This point of view supports Dr. Shaw's statement that approximately circular storms cannot be satisfactorily explained as revolving vortices of air carried along by currents of different velocities.

It is suggested that in future study the velocity of the storm centre should be taken as unity and the component air currents classified according to their velocities measured in terms of that unit.

Expressions for the accelerations of the air particles are found, viz.:—

Along the radius ... ... $-V\cos\alpha(V\cos\alpha+U\sin\theta)/r$

Perpendicular to the radius ... ... $-V\sin\alpha(V\cos\alpha+U\sin\theta)/r$.

The time along the relative curve is found to be given by:—

$$t-t_0=\lambda(A+B\sin\theta+C\cos\theta)r/U,$$

where

$$A=-(1+k^2)(1-\lambda^2+k^2)/k$$
$$B=-\lambda(1-\lambda^2+k^2)/k$$
$$C=\lambda(1-\lambda^2+k^2)$$

and

$$k^2=\tan^2\alpha(1-\lambda^2).$$

The coordinates of the path in space are then found to be

$$x=Ut+r\cos\theta$$
$$=[\lambda(A+B\sin\theta+C\cos\theta)+\cos\theta]r+\text{const}$$
$$y=r\sin\theta$$

together with the equation for r in terms of θ.

The particular case, studied by Dr. Shaw, where $U=V$ and $\alpha=0$ is then deduced, in the form

$$(y_0-y)(2y_0+y)^2=9y_0x^2.$$

3. *The Distribution of Atmospheric Pressure in Canada.* *By* R. F. Stupart.

4. *On the Size of Hailstones observed during a Storm in Western Canada.* *By* J. W. Shipley, *B.A.*

The author took the opportunity of recording the size and shape of hailstones that fell during a recent storm in the foot hills of the Rockies, some of which were larger than hen's eggs. At the centre of one hailstone a small black fly was found.

5. *Some Results of Stellar Parallax Investigations made at the Radcliffe Observatory, Oxford.* *By* Dr. A. A. Rambaut, *F.R.S.*

Within the last six years the astronomical equipment of the Radcliffe Observatory received an important addition in the shape of an equatorial instrument carrying two telescopes of 24 inches and 18 inches aperture respectively, the focal length of both being 22 feet 6 inches. A full description of the instrument will be found in 'Engineering' for December 21, 1906.

Preliminary observations having shown the suitability of the instrument for work of high precision, it was determined to apply it to the investigation of stellar parallax, adopting Kapteyn's photographic method. The immediate object of the research was to demonstrate the feasibility of a photographic 'Durchmusterung' for parallax extending to stars of the 13th or 14th magnitude. For this purpose nine regions of the sky were selected in consultation with Professor Kapteyn, and of these forty-six complete photographs, each consisting of twelve separate exposures, have been obtained. The work of measuring and discussing these plates is still in progress, but in this paper an account is given of some of the results already obtained.

Five plates representing the region surrounding the star Ll 5761 were sent to Professor Kapteyn and were measured and discussed by him at the Astronomical Laboratory, Groningen. This star is of magnitude 8·0, and its place for 1905·0

is R.A. $3^h\ 2^m\ 49^s{\cdot}97$, Decl. $+25°\ 59'\ 16''{\cdot}3$. It has a large proper motion—viz., $-0^s{\cdot}013$, $-0''{\cdot}88$ in R.A. and Decl. respectively. The separate results deduced from the five plates are as follows:—$0''{\cdot}004$, $+0''{\cdot}114$, $0''{\cdot}072$, $+0''{\cdot}051$, $+0''{\cdot}192$, from the mean of which we have as the parallax of this star, relatively to seventy-five comparison stars of mean magnitude 11·0,

$$+0''{\cdot}085 \pm 0''{\cdot}022.$$

The mean probable error of the parallax of one of the comparison stars as derived from the five plates is $\pm 0''{\cdot}013$.

At a later date two plates, 6 B and 54 B, representing the region around Weisse 6^h, 128 were sent to Professor Kapteyn at his request. The magnitude of this star is 8·4, and its position for 1905·0 is R.A. $6^h\ 9^m\ 55^s{\cdot}05$, Decl. $+44°\ 44'\ 43''{\cdot}4$. It has a proper motion of $-0^s{\cdot}028$ and $-0''{\cdot}33$ in R.A. and Decl. respectively. The separate results deduced by him from these two plates are $+0''{\cdot}136 \pm 0''{\cdot}018$ and $+0''{\cdot}067 \pm 0''{\cdot}020$, or, taking the mean, we have as the parallax of this star:

$$+0''{\cdot}102 \pm 0''{\cdot}013.$$

For the probable error of the parallax of one of the 166 comparison stars we have, using Kapteyn's notation (see Groningen Publications No. 12):

No. of Plate	ρ_3	ρ_1	ρ_1'
6B	$\pm 0''{\cdot}018$	$\pm 0''{\cdot}032$	$\pm 0''{\cdot}028$
54B	$\pm 0{\cdot}020$	$\pm 0{\cdot}035$	$\pm 0{\cdot}027$

The remainder of the plates will be measured and discussed at the Radcliffe Observatory and some progress has already been made with this work. The results for the double star, Ll 6888 and 9 ($= \Sigma$ 443) appear of sufficient importance to lay before the Section. This is a double star the components of which are of the magnitudes 8·5 and 8·8 respectively, and have a large common proper motion amounting to $+0^s{\cdot}053$ in R.A. and $-1''{\cdot}24$ in Declination. In this case the parallax factor is only 2·21—the normal factor being 4—and we find $\rho_3 = \pm 0''{\cdot}032$, $\rho_1 = \pm 0''{\cdot}055$, and $\rho_1' = \pm 0''{\cdot}030$.

On this plate there are 191 stars suitable for measurement. Grouping them according to magnitude, we find the following results:

Mean Parallaxes.

Limits — Mag.	Mean Parallax	No. of Stars
Brighter than 8·5	$+0''{\cdot}110$	5
8·5 – 9·5	$+0{\cdot}067$	7
9·5 – 10·5	$+0{\cdot}017$	25
Fainter than 10·5	$-0{\cdot}010$	154

The central star Σ 443 is most probably a binary system, and taking the mean of the results found for the separate components, we have as the parallax of this system relatively to 189 comparison stars—$\pi = +0''{\cdot}10 \pm 0''{\cdot}02$.

---

6. *Two curiously similar Spectroscopic Binaries. By* J. S. Plaskett *and* W. E. Harper.

MONDAY, AUGUST 30.

Discussion on Positive Electricity.[1]
Opened by Professor Sir J. J. THOMSON, *F.R.S.*

The following Papers and Reports were then read:—

1. *The Law of Distribution of Stellar Motions.* *By* A. S. EDDINGTON, *M.A., M.Sc.*

Professor Schwarzschild's hypothesis accounts for the existence of two favoured directions in the distribution of the proper motions of the stars by assuming an ellipsoidal modification of Maxwell's frequency law, so that the frequency of a stellar velocity (u, v, w) is proportional to

$$\varepsilon^{-g^2u^2-h^2(v^2+w^2)}$$

He has shown how to determine the constants of the ellipsoid from the observed statistics of the numbers of stars moving in the various directions.

The method can be extended so as to make use of the mean proper motions of stars, instead of the numbers of stars moving in the various directions, as the observed data. This can be done quite rigorously; but by making an approximation (which is always amply sufficient in practice) the following simple rule results: the radius of the velocity-ellipse in the direction θ is the geometric mean between the mean P.M. of stars moving in the direction θ and the mean P.M. of stars moving in the direction $\theta + 180°$. In this way it is easy to determine the velocity-ellipse for any region. For the seven regions of the stars of Groombridge's catalogue, I find the following values of the ratio of the minor and major axes of the velocity-ellipses (1) derived in this way and (2) derived from the numbers of proper motions.

Mean P.M.'s ... ·59, ·56, ·76, ·82, ·65, ·53, ·66, respectively. Mean ·65
No. of P.M.'s ... ·59, ·58, ·70, ·81, ·72, ·61, ·72, respectively. Mean ·68.

The agreement region for region is very satisfactory, and there appears to be no systematic difference between the results derived from the two kinds of data.

Another development of Schwarzschild's theory which it seemed worth while to investigate is the consideration of a velocity-ellipsoid having three unequal axes, in place of the spheroid which has hitherto been considered. It was conceivable that some of the discordances of the various determinations of the vertex might be reconciled in this way; but the special interest of the discussion lies in the question whether the distribution of stellar motions has a special relation to the galactic plane. It is now fairly well established that the greatest axis of the velocity-ellipsoid lies accurately in the galactic plane; but, apart from this preference for a particular axis in the galactic plane, is there a preference of stellar motions for the galactic plane in general? If the distribution of the stars is comparatively limited in the directions of the galactic poles, it might be expected that their velocities in these directions would be, on the average, smaller. We should then have a velocity-ellipsoid with three unequal axes, of which the least would point to the galactic poles. On comparing observation with theory, the evidence, though inconclusive, appears to be unfavourable to the hypothesis of an appreciable deviation of the velocity-ellipsoid from the form of a prolate spheroid.

---

[1] Published in *Engineering*, Sept. 17, 1909.

2. *The Variation of the Specific Heat of Mercury at High Temperatures.* *By* Professor H. T. Barnes, *D.Sc.*

In 1902 the author communicated to the British Association the preliminary results of an investigation of the variation of the specific heat of mercury with temperature between 0° and 100° C. Since then the work has been carried over a wider temperature interval, and it has been possible to extend the curve of variation towards the boiling-point of the mercury.

In the older work the continuous method of calorimetry was used, including much of the apparatus employed by the author in his measurements of the specific heat of water. Thus the thermometers were the same, as well as the Clark cells and resistance standards. It should be possible, then, to express the specific heat of mercury with considerable accuracy quite independent of any values assumed for the electrical standards.

The specific heat of mercury above 100° C. was also obtained by a continuous method, and therefore possessed the advantages of steady temperature conditions.

A stream of mercury was heated while flowing through a fine steel tube in the vapour of some suitable organic substance possessing a steady boiling-point up to the desired temperature. It then passed directly into the calorimeter, which was provided with an inflow and outflow tube fitted with thermometers. Directly through the heart of the mercury passed a fine glass tube, through which a stream of water at room temperature flowed. Thermometers in the water gave the rise of temperature, which with the flow gave a measure of the heat taken out of the mercury. The temperature fall in the mercury, together with a knowledge of the flow, gave a measure of the cooling effect produced, and hence, after correcting for heat loss, of the specific heat. By this method the flows were arranged so that the mercury was seldom cooled more than 40° C., while the water was not warmed more than 10° or 15° C. Thus the average specific heat could be determined at the high temperature over a comparatively small interval of temperature, while the heat extracted by the water could be measured over a temperature interval in which the specific heat of the water was accurately known. The heat loss was determined by special experiments with no water flowing. This was found to be proportional to the mean temperature of the mercury in the calorimeter. Having determined the heat loss for several mean temperatures between 100° and 200° the curve was plotted, and for each calorimeter the heat loss was read off for any intermediate mean temperature. Differential platinum thermometers were used to obtain the temperature, except in some of the experiments when sensitive mercury thermometers were placed in the water inflow and outflow. The readings of these mercury thermometers were reduced by direct comparison with a platinum thermometer.

The author has recalculated all of his older observations, and these results have been reduced to the normal hydrogen scale. The results obtained by the later work have been reduced to the same scale. It was not possible to obtain such accuracy in the later work as characterised the observations by the electrical method at the lower temperatures. This was partly due to want of water jacketing and to the impossibility of arranging a vacuum jacket about the calorimeter. Lagging was employed of asbestos string, wound on carefully, and glass wool. The observations check out to one or two parts in 1,000, and it is unlikely that the curve is in error by more than that, if as much. All of the observations at the lower range taken by the electrical method with water and vacuum jackets are of much greater accuracy. It is very unlikely that they are in error by more than one or two parts in 10,000.

The results of this investigation are chiefly interesting in showing that the specific heat of mercury passes through a minimum value at about 140° C. and increases fairly rapidly up to the boiling-point. In this respect it resembles water very closely, which possesses a minimum point at 37° C., or at about the same relative position between the freezing and boiling points in the two cases.

Specific Heat of Mercury at various Temperatures. Actual Observations.

Electrical Method		Water-cooled Method	
Temp.	Specific heat corrected	Temp.	Specific heat corrected
° C.		° C.	
2·93	0·033489	159·65	0·03287
4·45	0·033460	160·46	0·03297
18·37	0·033318	222·85	0·03291
24·52	0·033261	224·46	0·03304
31·68	0·033194	225·49	0·03299
32·44	0·033185	252·73	0·03309
36·59	0·033178	253·06	0·03309
45·00	0·033085	261·57	0·03321
53·39	0·033040	268·23	0·03318
65·22	0·033007		
83·89	0·032931		

3. *The Relation of Vocal Quality to Sound Waves.*
By T. Proctor Hall, *M.A., Ph.D., M.D.*

An apparatus for making enlarged tracings of sound waves from a cylindrical graphophone record, the magnification ranging from 150 to 2,500 times, was described. In the sound waves two elements are distinguished, impulse and resonance, which are illustrated by waves from the cornet, violin, bugle, &c. Vocal waves are found in groups regularly repeated. Each group contains a single impulse from the vocal cords, together with one or more sets of resonance waves produced by vibrations of the air in the vocal tubes. Pitch is determined by the number of impulses per second—*i.e.*, by the number of wave groups—and is not affected by the character of the waves within the groups. The vowel quality of vocal sounds is not perceptibly affected by the number or form of the resonance waves, but is dependent upon their periodicity. The rate of the resonance waves may be calculated from the length of the air tubes upward from the vocal cords. The calculation shows, for example, that the sounds m, n, ng, all contain a resonance wave whose period is about 530. The mean rates found from measurements of the enlarged waves are for m 550, for n 535, for ng 580. The observed rate for the sound of ‘ a ’ in the word ‘ great ’ is 420, and for the sound of ‘ a ’ in ‘ mat ’ 770 waves per second. The investigation is continued.

---

4. *Electric Splashes on Photographic Plates.*
By Alfred W. Porter, *B.Sc.*

The author exhibited lantern slides of the figures obtained by developing photographic plates over which electric discharges had been allowed to spread. These were in extension of a series shown to the Physical Society of London last November. Splashes with different gases surrounding the plate prove, from their great dissimilarity in the case of ‘ negative ’

splashes, that the surrounding gas practically determines them. In the case of 'positive' splashes the surrounding gas has very small influence. If the pressure of the surrounding air is reduced, the appearance completely changes. At a pressure of about 17 cms. in air the negative splash has a very definite appearance, showing two new dark spaces with triangular 'squirts' of discharge extending between them.

The radical difference between positive and negative discharges is very pronounced. If a triangular or rectangular electrode is placed on the plate, the branched figures obtained tend to leave at the corners of the plate when this electrode is made positive, but to leave at the sides (and at right angles thereto) when it is the negative terminal.

The effects of a magnetic field and of a blast of air over the plate were also exhibited.

5. *The Photographic Action of Alpha Rays.* *By* T. Kinoshita.

6. *On Secondary Radiation by Gamma Rays on Different Metals.* *By* Professor A. S. Eve.

7. *On the Active Deposits from Actinium in Uniform Electric Fields.* *By* W. T. Kennedy, *M.A.*

In this paper an account was given of some measurements on the amount of active deposit from actinium obtained at different pressures on two parallel plate electrodes provided with guard rings and placed about 2 mm. apart.

The deposits were obtained on both electrodes under a field of 250 volts.

As the pressure was decreased from atmospheric the amount of active deposit on both electrodes gradually increased, passed through a maximum value, and finally at low pressures rapidly decreased. The maximum activity was obtained at different pressures for the two electrodes, in each of the gases hydrogen and carbon dioxide and in air, and the maximum cathodic deposit was found to be about 2·7 times that obtained on the anode in each of the gases.

The total deposit on the two plates obtained in air at varying pressures was found to be approximately the same, whether an electric field was applied or not. The total active deposit was also found to be increased on both electrodes when potentials higher than the sparking ones were applied. The relative coefficients of diffusion for the emanation from actinium were found to be—Carbon dioxide, 1; air, 1·3; and hydrogen, 4·2.

8. *The Effect of Light on Sulphur Insulation.* *By* F. W. Bates.

During a series of experiments on the ionisation of the air in closed vessels, the author used an electroscope in which the leaf system was supported on sulphur insulators. When an attempt was made to calibrate the instrument, large variations in the rate of leak were noticed, which seemed to depend on the intensity of the light falling on the leaf system. A series of experiments was then undertaken to discover whether any such definite relation existed.

It was found that the average day-rate of leak was greater than the average night-rate, that bright sunlight falling on the insulator increased the rate very greatly, while even partially excluding the light decreased it perceptibly. By intercepting some of the sun's rays by means of either cobalt blue or red glass the rate of leak was much lessened, and by totally

excluding the light from the insulation the day-rate of leak was reduced to practically the same as the night-rate.

The theory that this change of rate of leak was due to a rapid and violent change in the rate of ionisation of the air in the vessel was early abandoned, for it was found that by merely causing the sunlight already shining into the vessel to fall directly on the sulphur insulation a great increase in the rate of leak was obtained, although there was no more sunlight entering the electroscope than formerly. The theory that sulphur is affected in much the same way under sunlight as zinc is under ultra-violet rays was also abandoned, for it was found that positive and negative charges leaked equally fast under similar conditions. An electroscope was constructed with a guard-ring about the sulphur insulation which was on the exterior of the vessel, and thus completely exposed to the light.

In daylight, when the guard and the leaf carried charges opposite in sign, the leaf lost its charge, and in time acquired a charge similar in sign to that on the guard; but when both guard and leaf carried the same kind of charge, the charge on the leaf increased if initially less than that on the guard, but decreased if initially greater. On the other hand, at night either kind of charge leaked away from the leaf, even with the guard charged, which was undoubtedly due to the ionisation of the air in the vessel.

The conclusion is that sulphur in the presence of light becomes to a slight degree a conductor of electricity, and the greater the intensity of the light, the greater the conductivity; and, further, that the leak due to ionisation is less than that due to the increase in the conductivity of sulphur, exposed even to ordinary daylight. It is necessary, therefore, that great care should be taken when measuring small electrical changes with instruments having sulphur insulation to keep light from falling on the sulphur.

A series of preliminary investigations in which amber and ebonite were used as insulators indicated a slight increase in the conductivity of ebonite in *strong* sunlight, but amber did not show any such effect. The importance of the effect of light on insulation was so great that the writer purposes investigating thoroughly with these and other materials in order to find its extent, and also, if possible, to discover the exact nature of the change produced by light on sulphur.

---

9. *The Charge on Gaseous Ions.*
By T. FRANCK *and* Dr. W. WESTPHAL.

J. S. Townsend[1] has shown that by X-rays doubly charged ions are generated. Recent experiments made by the author[2] lead to the conclusion that these doubly charged ions are only a small part of the total ionisation, and that generation in an electric field, contrary to Townsend's view, has nothing to do with their formation. The coefficient of diffusion of the ions generated by X-rays, as measured by the method of Townsend,[3] may be reduced to half the value of singly charged positive ions by placing some wire gauze in the way of the ions, which causes a kind of fractionated diffusion, more of the easily diffusing singly charged ions being lost in the holes than of the double ones. If we assume that practically all singly charged ions have been removed by the wire gauze, the coefficient of diffusion of the double ions is thus found to be half that of the single ones.

From the point of view of Rutherford's cluster theory of the ions, this

[1] *Proc. Roy. Soc.* May 1908.
[2] *Verh. Deutsch. Phys. Ges.* 11, 146, 1909; 11, 276, 1909.
[3] *Phil. Trans.* (*A.*) 193, 129, 1900.

result indicates that the doubly charged ions carry double mass, while it would agree as well with the new theory of Sir J. J. Thomson and Wellisch, from which follows that a double charge reduces the coefficient of diffusion, even when the mass remains unaltered. In this case the coefficient of diffusion may be still smaller than the measured value.

With α, β, γ rays and point discharge no doubly charged ions were found. In the case of point discharge, the formation of big charged complexes, due to chemical processes, was proved to occur.

---

10. *The Recombination of Ions in Air at Different Temperatures.* *By* Dr. P. Phillips.

Langevin has shown that McClung's original experiments on this subject were quite spoiled by diffusion owing to the electrodes being too near together, and to the intense ionisation which existed at the surface of the electrodes.

L. L. Hendren has shown experimentally that diffusion is almost negligible at the temperature of the laboratory and at atmospheric pressure if the distance between parallel electrodes is at least 2 cms. and the ionisation is uniform between them.

In the present experiment Langevin's method for finding the recombination is adopted. The rays produced by a single discharge in a Röntgen bulb ionise a layer of air between two parallel electrodes, one of which is connected with a Dolezalek electrometer, and the other raised to any desired potential. The parallel electrodes are about 3 cms. apart, and the layer of ionised air about 1·5 cm. thick, thus leaving spaces of about ·75 cm. between the surfaces of the ionised layer and the electrodes. Under these circumstances, it is probable that diffusion may be safely neglected, but in any case more rapid diffusion would here make the recombination appear slower.

The electrodes are surrounded by a jacket through which vapours from liquids boiling at known temperatures may be circulated.

In essence the experiment consists in measuring the charges received by the electrometer when different fields are established between the electrodes. This is done first at the temperature of the laboratory and then at the temperature of the boiling liquid. From a comparison of the two series of readings, the ratio of the coefficients of recombination at the two temperatures may be calculated, the coefficient at the temperature of the laboratory being taken as unity.

The following results have been obtained up to the present, and they show that α decreases somewhat rapidly with a rise of temperature:

Temperature	α	Mr. Erikson's values
15° C.	1·00	1·00
100	·50	·51
155	·40	·405
178	·36	·38 (extrapolating a little)

Since completing the above experiment, Mr. Erikson has published a paper on the same subject. Using ionisation from radium, and with an entirely different method, he gets almost identical results. These are shown in the third column of the table for comparison.

---

11. *The Terminal Velocity of Fall of Small Spheres in Air.* *By* Professor John Zeleny *and* L. A. McKeehan.

To test Stokes's formula for air, the size, density, and the terminal velocity of fall of some spherical spores were determined.

The following results were obtained:

Substance	Radius	Density	Terminal velocity	Velocity according to Stokes's formula
	cm.		cms./sec.	
Lycoperdon .	0·000207	1·44	0·0465	0·0757
Polytricum .	0·000478	1·53	0·228	0·417
Lycopodium .	0 00158	1·175	1·77	3·52

12. *Report on the Magnetic Observations at Falmouth Observatory.* See Reports, p. 36.

13. *Report on the Geodetic Arc in Africa.*—See Reports, p. 37.

14. *Eighth Report on the Investigation of the Upper Atmosphere by Means of Kites.*—See Reports, p. 37.

15. *Report of the Committee on Electrical Standards.* See Reports, p. 38.

16. *Report of the Seismological Committee.*—See Reports, p. 48.

17. *Report of the Committee to aid in Establishing a Solar Observatory in Australia.*—See Reports, p. 66.

TUESDAY, AUGUST 31.

Discussion on 'Earth Tides.'
Opened by Professor A. E. H. Love, *F.R.S.*

Lord Kelvin showed (1863) that, if the earth could be regarded as homogeneous and absolutely incompressible and possessed of the same degree of rigidity as steel, the oceanic tides of long period would be reduced, owing to the yielding of the earth, to about two-thirds of the theoretical heights which they would have if the substance were absolutely rigid. Sir G. Darwin (1881) estimated the actual height of the fortnightly tide as about two-thirds of the theoretical height. Attempts to measure directly the lunar disturbance of terrestrial gravity were made by several observers, and recently Dr. O. Hecker, by using two horizontal pendulums mounted in an underground chamber, has demonstrated the existence of the corporeal tide, and has shown that the actual deflexion of such pendulums is about two-thirds of what it would be if the earth were absolutely rigid. This result means that, besides the tide-raising force of the moon (F), there act on the pendulum other forces arising from the deformation of the earth. These forces are (i) the component of undisturbed gravity tangential to the deformed surface, denoted by hF; (ii) a genuine disturbance of gravity, consisting in the attraction of the tidal protuberance and other related

changes of the attraction of the mass of the earth, denoted by kF. The results obtained by Darwin and Hecker, and confirmed by Schweydar, show that the two numbers h and k are connected by the equation $h-k=\frac{1}{3}$. From this result alone we cannot determine either h or k, and so cannot determine the actual height of the corporeal tide without having recourse either to hypothesis or to new observations. If we adopt Kelvin's hypothesis, we find $k=\frac{3}{5}h$, and thence $h=\frac{5}{6}$, $k=\frac{1}{2}$, and the corresponding estimated height of the corporeal lunar tide is about 46 cm. If, however, we bring in the fact of observation, discovered by Dr. S. C. Chandler, viz., that the period of variations of latitude (about ten months if the earth were absolutely rigid) is actually about fourteen months, we can determine k in terms of known quantities. Variations of latitude imply an adjustment of the earth's figure to rotation about an instantaneous axis which does not quite coincide with a principal axis. The corresponding inequality of 'centrifugal force' has the same effect as a certain external force producing a deformation of the earth and a genuine disturbance of gravity. If the force in question is denoted by F, the genuine disturbance of gravity may be denoted by kF, where the coefficient k is necessarily the same as in the tidal problem. It has been proved independently by Sir J. Larmor and the author that k is about $\frac{4}{15}$. It thence appears that $h=\frac{3}{5}$ approximately, and that the height of the corporeal lunar tide is about 33 cm. The earth would accordingly appear to be more rigid than Lord Kelvin estimated it to be, a result confirmed by the interpretation of seismographic records.

Department of General Physics.

The following Papers were read:—

1. *The Lengthening of Loaded Wires when Twisted.* *By* Professor J. H. Poynting, *F.R.S.*

An analysis of a pure shear, taking into account quantities of the order ϵ^2, where ϵ is the angle of shear, shows that there may be a pressure perpendicular to the planes of shear proportional to ϵ^2. If this applies to a twisted wire and the pressure is not applied the wire should lengthen on twisting. The author described experiments on steel, brass, and copper wires, all of which when loaded sufficiently to take out kinks showed a lengthening $\delta l=\frac{1}{2}sa^2\theta^2/l$, where a is the radius, l the length, θ the angle of twist, and s is for steel about 1, for copper and brass about 1·6.[1]

2. *The Angular Momentum in a Beam of Circularly Polarised Light.* *By* Professor J. H. Poynting, *F.R.S.*

From the analogy of a shaft revolving uniformly and transmitting strain and energy with the 'natural' velocity $\sqrt{\text{rigidity} \div \text{density}}$ the suggestion is obtained[2] that the angular momentum given per second to a normal receiving surface by a beam of circularly polarised light of wave-length λ and energy E per c.c. is $E\lambda/2\epsilon$.

[1] See *Proc. Roy. Soc.*, A, vol. lxxxii. p. 546. [2] *Ibid.* A, vol. lxxxii. p. 560.

3. *The Effect on the Persistence of Vision of Fatiguing the Eye with Red, Orange, and Yellow.* By Professor Frank Allen, *Ph.D.*

In order to determine the persistence of vision a sectored disc is rotated in front of the slit of a spectrometer at such a speed that the flickering of the colour is made to just disappear. This critical speed is very accurately measured electrically by means of a chronograph. A persistency curve can then be obtained which is shaped like a parabola with its apex at the point corresponding to the brightest part of the spectrum. If the eye is constantly fatigued with some colour and the persistency now measured, the two persistency curves when plotted together show some peculiar and characteristic differences. When the eye is fatigued with red light of wave-lengths 680 and 670, the fatigue curve differs from the normal only in the part corresponding to red. When the eye is fatigued with green, the two curves differ in the green alone. But when the fatiguing colour is any part of the spectrum between wave-lengths 577 and 650, the curves differ in both red and green. When, however, the wave-length 660 is used as the fatiguing colour, the two curves coincide completely. This means that the fundamental red sensation is at least beyond wave-length 660, and that yellow and orange cannot be simple primary sensations.

---

4. *A New Method of Measuring the Luminosity of the Spectrum.* By Professor Frank Allen, *Ph.D.*

The principle upon which this method depends is that the persistence of a colour sensation on the retina is a function of the luminosity of the colour only.

Two Nicol prisms are mounted in front of the spectrometer slit. It is so arranged that in the eyepiece one sees two small adjoining patches of light, one white, the other all colours of the spectrum in succession. The white light is of such low intensity that its persistence is the same as that of very weak violet light. By rotating the polariser the intensity of the spectrum colours is reduced to that of the standard white. The intensity of the light going through the Nicols being proportional to the square of the cosine of the angle between their principal planes enables the luminosity to be determined.

A sectored disc rotating in front of the slit interrupts both white and coloured lights at the same time, thus enabling the persistence of the flashes of light to be measured.

---

5. *The Effect of Low Temperatures on Fluorescence Spectra.* By Professor Edward L. Nichols *and* Ernest Merritt.

This is a quantitative spectrophotometric study, by methods previously employed by the authors and described in various papers, of the spectra of certain fluorescent substances at temperatures between +20° C. and −185° C.

The bodies subjected to measurement were:—

(1) A specimen of natural willemite in powdered form;

(2) Commercial anthracene showing the green fluorescence bands of the impure preparation;

(3) An alcoholic solution of fluorescein;

(4) An alcoholic solution of resorufin.

Excitation was produced by means of a quartz-mercury lamp any portion of the spectrum of which, dispersed through quartz, could be focussed on the surface of the fluorescent body. The latter was placed in an enclosed

chamber to prevent the deposition of frost. Cooling was effected by liquid air applied from below to a metal tube at the upper end of which was the substance, while the lower end was submerged to various depths in a Dewar flask. Temperatures were determined by means of the resistance of a coil of pure copper wire surrounding the capsule containing the substance.

The measurements consisted in comparing the brightness of the fluorescence spectra, wave-length by wave-length, with that of an acetylene flame which had previously been similarly compared with the spectrum of the light from an ideal black body of known temperature.

The results are exhibited by means of three sets of curves.

(1) Curves giving the variations of brightness of the fluorescence spectrum with wave-length at a given temperature. These show the form of the fluorescence bands, their changes in intensity and breadth and their shift in wave-length as the temperature diminishes.

(2) Curves giving the variations of intensity of a given wave-length with change of temperature.

(3) Curves giving the shift in wave-length of regions of equal brightness in the fluorescence spectra with change of temperature.

---

6. *Absorption and Fluorescence of Canary Glass at Low Temperatures.* By R. C. Gibbs.

The specimen of glass studied was obtained from the Geophysical Laboratory at Washington, and was prepared according to the following formula: SiO_2 70 per cent., K_2O 24 per cent., CaO 6 per cent., to which 2·5 to 3·0 per cent. sodium uranate is added.

In order to study the absorption and fluorescence at low temperatures the glass, a rectangular plinth, was mounted in an unsilvered cylindrical Dewar bulb with proper screening, to avoid stray light. The observations were made with a Lummer and Brodhun spectro-photometer. For measuring the absorption an acetylene flame was placed so that by means of reflectors light could be made to illuminate the comparison slit, and also by another path to pass through the glass to the other slit of the spectro-photometer. A Cooper-Hewitt mercury lamp, placed so as to illuminate the surface of the glass parallel to the direction in which the light passed through the glass when studying the absorption, was used to excite fluorescence, the intensity of which was compared with that of an acetylene flame.

The intensities of transmission and fluorescence were measured at five or six different temperatures, chosen at fairly regular intervals, from room temperature down to $-175°$ C. Cooling was secured with liquid air, and the temperature measured with a thermo-junction by the potentiometer method. During any particular run through the spectrum the temperature was kept constant within two degrees. Extreme care was taken to eliminate frost or moisture from the surface of any of the glass through which the light passed.

The glass shows considerable absorption throughout the spectrum, but the maximum occurs in the violet end and extends up to about ·51 μ. The decrease in temperature produces a decrease in absorption in all parts of the spectrum measured, the change being very slight in the yellow and red, while from ·45 μ to ·54 μ the transmission intensity increased from 15 to 25 per cent.

The main fluorescence band extends from ·48 to ·59 μ. At room temperature the fluorescence corrected for absorption shows a rather broad band with a slight indication of two maxima between ·51 μ and ·535 μ. The curve is steeper on the violet side than on the red. With decreasing temperature the fluorescence for the most part increases, the maximum

increase being about 100 per cent. The two maxima just mentioned develop decidedly, so that at the lowest temperature reached the fluorescence shows two narrow overlapping bands, one with a maximum at ·514 μ and the other at ·633 μ. While the steepness of the curve increases on both sides of these bands, yet it is much more marked on the violet side, there being a slight decrease in fluorescence on that side at the base of the band for the lower temperatures.

Department of Cosmical Physics.

The following Paper and Report were read:—

1. *Seasonal and Storm Vertical Temperature Gradients.* *By* Professor W. J. Humphreys.

2. *Report on the Present State of our Knowledge of the Upper Atmosphere.*—See Reports, p. 71.

WEDNESDAY, SEPTEMBER 1.

Department of General Physics.

The following Papers were read:—

1. *The Effect of Temperature Variations on the Luminous Discharge in Gases for Low Pressures.* *By* Robt. F. Earhart.

The apparatus used in this investigation consisted of a small glass bulb, in which two parallel electrodes were sealed. These electrodes were 5 mm. apart. Suitable tubes permitted the bulb to be evacuated, the pressures being measured with a McLeod gauge.

The bulb was contained in an electric furnace, which could also be used as a container for carbon dioxide snow when measurements for discharges occurring at low temperatures were taken.

Potentials required to produce a luminous discharge for pressures varying from 0·2 mm. to 5 mm. were made, and for temperatures varying from −78° C. to 325° C. The gases operated upon were air, hydrogen, and carbon dioxide.

Potentials required to maintain the luminous discharge under similar conditions were also measured. Families of curves showing the effects of temperature and pressure for potentials required both to produce and to maintain luminous discharge were given.

They indicate that Paschen's law holds approximately for the discharge in air until temperatures in the neighbourhood of 300° C. are attained. Here Paschen's law does not hold even approximately. The effect of temperature variation on the potential required to maintain the discharge is much less than for the production of the initial discharge.

2. *Diffraction of Electric Waves.* *By* Professor H. M. Macdonald, *F.R.S.*

3. *The Instantaneous Propagation of a Disturbance in a Dispersive Medium.* *By* Dr. T. H. Havelock.

---

4. *The Relative Motion of the Earth and Æther and the FitzGerald-Lorentz Effect.* *By* C. W. Chamberlain.

To explain the negative results of the Michelson-Morley experiment to test the relative motion of the Earth and æther FitzGerald and Lorentz suggested that the motion of translation of a solid through æther produces a contraction in the direction of the drift, with extension transversely, the amount of which is proportional to the square of the ratio of the velocities of translation and of light.

Analysis shows that the total effect of the relative motion of Earth and æther is a displacement of the interfering rays in the line of sight, and at right angles to the line of sight. The displacement in the line of sight should have been detected if it was not counteracted by the FitzGerald-Lorentz effect. The displacement at right angles to the line of sight does not alter the distance of the interfering rays from the focal plane of the telescope, and therefore does not shift the interference system seen in the interferometer.

The displacement at right angles to the line of sight, which is not counteracted by the FitzGerald-Lorentz effect, should be detected by means of the *Diffractometer*—a combination of an interference system and a diffraction grating. It is proposed to produce interference between two rays of light which have travelled paths at right angles to each other. The interfering rays will be received by a diffraction grating. If one of the paths of the interference system is made longer than the other, interference fringes may be made to appear either in the spectra to the right or to the left, when the lines of the gratings are parallel to the interference fringes. If the length of path of the interference system is $5{\cdot}5 \times 10^7$, as in the Morley-Miller experiment, and a grating having 30,000 lines to the inch is employed, a shift of one interference band may be expected when the apparatus is rotated through ninety degrees.

---

5. *On some New Methods under Trial for Tables of the Moon's Motion.* *By* Professor E. W. Brown, *F.R.S.*

---

6. *A Cemented Triple for Spectroscopic Use.* *By* Lieut.-Colonel J. W. Gifford.

It was my privilege to exhibit at the Dublin Meeting an apochromatic triple for astronomical purposes. This objective had an aperture of three inches, a focus of 37·5 inches, and the focal lengths equalised were for wave-lengths 7066 (He), 5067 (Pb), and 4678 (Cd). The method of obtaining the refractive indices of the glasses used and the formulæ used for calculations have already been described.[1] With this objective it was difficult to trace any residual colour, the secondary spectrum having been very perfectly eliminated, but the ratio of aperture to focus was as great as 12·5. For spectroscopic purposes a greater light grip is desirable. This was obtained by a different combination of glasses, without, however, seriously sacrificing the practical coincidence of focus for all wave-lengths.

The glasses employed were Mantois's Borosilicate Crown, Schott's O31393 Borosilicate Flint, and Schott's O3187 Baryta Light Flint. The wave-lengths equalised for focus were 7682 (Kd), 5607 (Pb), and 4341 (H).

[1] *Proc. R.A.S.*, vol. lxix. No. 2.

With such a combination the ratio of effective aperture to focus reaches 7·5 as against 12·5 for the astronomical triple above referred to, or, in other words, it has nearly three times the light grip. It is likewise free from secondary spectrum, but the remaining tertiary spectrum becomes rather more prominent when, the mean force having been expanded to 60 feet, a focal curve is drawn. For ordinary powers it is still difficult to detect.

The radii of the spherical surfaces for such a triple are quite moderate, viz.:

1st surface	3·961
2nd and 3rd	3·377
4th and 5th	1·771
6th	27·174

and the greatest curvature sum is:—

$$\frac{\frac{1}{f}}{\mu-1}=\frac{-5\cdot535}{0\cdot572}=-9\cdot684.$$

Professor Hastings's well-known requirements being that no one of the curvature sums should exceed 30. All inner surfaces are cemented.

For spectroscopic purposes two of these triples (respectively for collimator and telescope) are placed at such a distance apart that their nodal planes are coincident, thus forming a symmetrical doublet.

The lens shown was constructed for me by Messrs. Hilger, Ltd., of London. It is in use as a telescope lens, with power of 56 diameters, focussed on a test object, a suitable spectroscope not being at hand. Its aperture is $1\frac{1}{2}$ inch, its focus $11\frac{1}{4}$ inches.

A doublet, designed for deer-stalking, of $1\frac{1}{2}$ inch aperture and $8\frac{1}{4}$ inches focus with a power of 40 diameters was also shown.

---

7. *On Magnetostriction.* *By* H. G. Dorsey, *Ph.D.*

What I wish to present is the result of recent rather exhaustive experiments on magnetostriction on a series of eight steel rods of known chemical contents and tested in different physical conditions.

I have found that the maximum elongation is a function of the carbon content, the curve being similar to a curve in the iron-carbon phase diagram; also that there is a rather definite relation between the maximum elongation and the maximum susceptibility of any specimen of iron, and the results of other workers seem to fit my curve pretty well. The maximum retraction in a given field bears an inverse relation to Young's modulus.

I also show that a correction should be applied to the changes in length, and that this correction is of the same nature as the correction to be applied in magnetic work to correct for the demagnetising effects of the ends of the rods.

The upper and lower limits of my experiments include practically all the results found in the fifty or more articles published since Joule's discovery of this phenomenon in 1842, and thus tend to unify the rather chaotic condition of conflicting experimental results.

---

8. *The Photographic Registration of Sound Waves.* *By* Professor Drayton C. Miller, *D.Sc.*

For the quantitative study of the tone quality of musical instruments it seemed necessary to have photographic records of sound-waves which would be more accurate and more directly obtained than those heretofore used.

A minute mirror is mounted on a very small cylindrical steel staff which is capable of rotation in delicate jewelled bearings. A fibre is attached to the centre of a diaphragm, passes around a small pulley on the staff, and is kept taut by a spring. When a sound-wave impinges upon the diaphragm the mirror is given rotation proportional to the displacement of the diaphragm. The moving parts have a mass of less than 3 milligrams, and are so designed as to have a minimum moment of inertia. The radius of the pulley is 0·3 millimeter, and a moving photographic film is placed at such a distance that light reflected from the mirror to the film records the movements of the diaphragm magnified 2,000 times.

The records exhibited showed: simple sine curves from tuning-forks, and the combination of these; the separate and combined curves from an organ-pipe and a whistle having a frequency of more than 3,000; the curves from a flute, and from a bell. The following records of spoken words are shown: one record of the words 'sound-waves,' one record of the words 'Karl Fischer,' five different records of the word 'fish,' and four different records of the words 'Lord Rayleigh.' The quantitative analysis of such records is in progress.

Department of Cosmical Physics.

1. *The Highest Meteorological Observations in America.* *By* Professor A. Lawrence Rotch.

Although numerous observations with *ballons-sondes,* extending to great heights above the interior of the American continent, were made by the author in 1904-7 at St. Louis,[1] such data were not available in the eastern United States until last year, the maximum altitude at which the temperature was obtained, 7,040 metres, having been reached by kites flown from Mount Weather, in Virginia.

By limiting the duration of the ascensions of the *ballons-sondes,* they were successfully used by the author at Pittsfield, Mass., about 150 miles from the Atlantic coast, in May and July, 1908. Three instruments of the four sent up were recovered, that on May 7 having an excellent record of temperature to a height of 17,700 metres, which exceeds by 650 metres the highest ascension at St. Louis. The warm stratum, described in the author's previous paper, was penetrated further than ever before in America, the minimum temperature of $-54·5°$ C. occurring at 12,500 metres, whereas $-45·6°$ was recorded 3,000 metres higher, the stratum above being nearly isothermal, as shown by the spring ascensions at St. Louis. The height of the inverting layer and the minimum temperature agreed approximately with the averages for May over the interior of this continent. Two other ascensions from Pittsfield to 6,100 and 9,700 metres respectively, although they did not reach the great inversion, showed the characteristic stratification of the atmosphere, with a rise of temperature in the lower clouds and an accelerated fall of temperature with increasing height.

---

2. *The Thermal Structure of the Atmosphere over the British Isles, July* 27-29, 1908. *By* Dr. W. N. Shaw, *F.R.S.*

---

3. *Results of Twenty-five Registering Balloon Ascents from Manchester during the period June* 2, 7 P.M., *to June* 3, 7 P.M., 1909. *By* W. A. Harwood, *M.Sc.*

The ascents were made in connection with the work carried on at the Howard Estate Observatory on Glossop Moor. The balloons used were of thin rubber, filled with hydrogen, and had a free lift of about 300 gm.,

[1] *Report,* Dublin Meeting, 1908, p. 594.

giving a vertical velocity of ascent of about 3 m.p.s. The instruments were the light meteorographs designed by W. H. Dines, F.R.S., and weighed, with the protecting case, about 60 gm. Table I. gives the average temperature at different heights deduced from the nineteen records obtained.

TABLE I.—*Average Temperature at successive Kilometre Levels during the period June* 2, 7 P.M., *to June* 3, 7 P.M., 1909.

Height. Kilometres	Temperature ° C.	Height. Kilometres	Temperature ° C.
0	11	10	−47·5
1	3	11	−49
2	0	12	−47
3	−4	13	−46
4	−8·5	14	−46·5
5	−15	15	−47·5
6	−22	16	−48·5
7	−28·5	17	−48
8	−35	18	−48
9	−42		

Almost all the balloons fell within a range of 100 km. They were fairly uniformly distributed along a line between the points 80 km. N. 56° E. and 30 km. N., the early ones falling at the former, the later ones at the latter point.

It is seen that the temperature fell rapidly to a height of about 10 km., the average gradient being 5·7° C. per kilometre. Above this height there was a sharp rise of temperature, but above 12 km. the changes were small.

TABLE II.—*Temperature at successive 2-Kilometre Intervals during the period June* 2, 7 P.M., *to June* 3, 7 P.M., 1909.

Time	Height in Kilometres									
	0	2	4	6	8	10	12	14	16	18
7 P.M.	13·1	1	−9·5	−24	−34	−40·5	−48·5	−46	−51	−52
8 ,,	—	—	—	—	—	—	—	—	—	—
9 ,,	10·9	−0·5	−9·5	−23	−36	−50·5	−46	−47·5	−51·5	—
10 ,,	—	—	—	—	—	—	—	—	—	—
11 ,,	9·8	−2	−11·5	−23	−34·5	−44	−54·5	—	—	—
12 midnight	—	—	—	—	—	—	—	—	—	—
1 A.M.	8·2	−4	−12·5	−26	−41	−52·5	−49	−51	−52·5	−52·5
2 ,,	—	—	—	—	—	—	—	—	—	—
3 ,,	7·3	−2	−9·5	−22·5	−34	−46·5	−48·5	−46·5	−48·5	−50
4 ,,	—	—	—	—	—	—	—	—	—	—
5 ,,	7·5	−1	−6·5	−23·5	−35	−46	−45	−47	−48	−48
6 ,,	7·8	−3·5	−12·5	−24·5	−36·5	−48·5	−46	−46·5	−49	−48·5
7 ,,	—	—	—	—	—	—	—	—	—	—
8 ,,	—	—	—	—	—	—	—	—	—	—
9 ,,	11	+1·5	−6	−20	−31·5	−44·5	−42·5	−42	−44·5	−43·5
10 ,,	13	+0·5	−8·5	−21	−33·5	−45·5	−47	−45·5	−46·5	—
11 ,,	—	—	—	—	—	—	—	—	—	—
12 noon	14	+1·5	−5·5	−17·5	−30	−46	−45	−43·5	−44·5	−44·5
1 P.M.	—	—	—	—	—	—	—	—	—	—
2 ,,	14·6	+1	−9·5	−19·5	−33	−44·5	−45·5	−43·5	−44·5	−45·5
3 ,,	14·7	+0·5	−8	−20	−34	−48·5	−50·5	−45·5	−49	−47·5
4 ,,	14·5	0	−8	−19·5	−34	−47·5	−48	−50·5	—	—
5 ,,	—	—	—	—	—	—	—	—	—	—
6 ,,	13·6	0	−8	−21	−37	−52·5	−50	−48·5	−49·5	−48
7 ,,	12·6	−0·5	−10	−25	−41·5	−55	—	—	—	—

Table II. gives the values obtained at different heights at hourly intervals. The results indicate a very considerable diurnal variation of temperature even at a height of 10 km., but the irregularities are too great to allow very accurate deductions to be drawn. The fact that the variation is similar at all heights up to 10 km., and that solar radiation has no appreciable effect on the highly polished instrument at low altitudes, seems to point to a real variation, as shown by the curves. On the other hand, the increase of the amplitude of the variation with increasing height appears to indicate that it is due to insolation.

During the ascents the region was under the influence of an anticyclonic system of moderate intensity, whose centre was situated N.W. of Ireland. The pressure distribution changed but slightly during the period considered.

---

4. *A Balloon Spectrograph.* *By* Professor W. J. HUMPHREYS.

---

5. *The Effect of Atmospheric Pressure upon the Earth's Surface.* *By* F. NAPIER DENISON, *F.R.Met.Soc.*

Since the year 1899 the author has taken up the study of slow-period movements of the Milne horizontal pendulum, which has been in constant operation here from 1899 to the present time.

In order to make a thorough investigation of this phenomenon he has measured the photographic records from this instrument with a millimetre scale, and has noted the amounts and times of occurrence of all changes, including the diurnal and longer-period deflections.

These observations have been entered into a specially designed register, and, as they are often of sufficient amplitude to necessitate the resetting of the boom by altering the levelling adjustment, they have been corrected to form a continuous record.

By studying the earlier observations with the Victoria daily weather charts of the Pacific slope the author became convinced that most of these movements were due to meteorological causes.

A daily curve of the pendulum's movements for 1899 was plotted, and formed the material for a paper, entitled 'The Seismograph as a Sensitive Barometer.' This was read before the Royal Meteorological Society in June 1901. Later in the same year the author personally presented at the Glasgow Meeting of the British Association an illustrated paper upon the same subject derived from the plotted curves for 1899 and 1900 in conjunction with the weather charts of the Pacific slope.

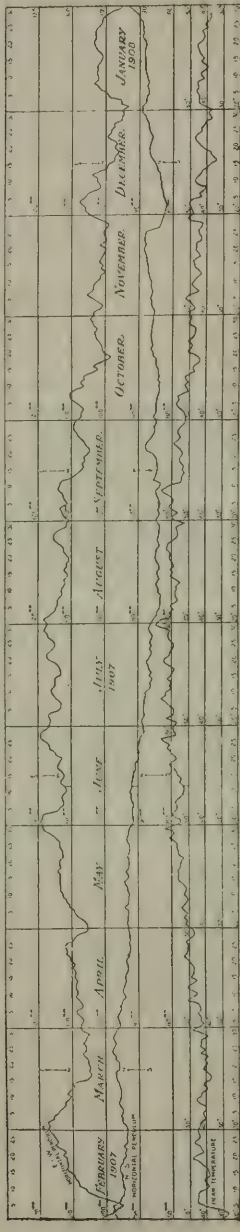
Acting upon the advice of Sir George Darwin, to obtain more data bearing upon this subject, and to install another horizontal pendulum to swing N-S, in order to study this direction of tilting in conjunction with the 'Milne' E-W pendulum, the author has succeeded in keeping a constant record of the E-W movements, and in January 1907 he personally constructed a simple form of horizontal pendulum. This is set up on the solid rock in the basement of the Victoria Post Office; it swings N-S, and is about 500 feet from the E-W instrument.

The accompanying diagram, which was part of a paper published by the Royal Astronomical Society of Canada in 1908, shows the daily movement of both pendulums, and the mean daily temperature from February, 1907, to January 31, 1908.

The upper curve represents the movements of the E-W pendulum, whose period of vibration is fifteen seconds and its angular value 0·76. The intermediate curve shows the N-S movement, which, having a ten-minute period of vibration, is not so sensitive as the former instrument. The lower curve gives the mean daily temperature.

There is a remarkable correspondence between the two pendulum curves—that is, when the E-W pendulum swings towards the west the N-S one

EAST-WEST AND NORTH-SOUTH HORIZONTAL PENDULUM MOVEMENTS AT VICTORIA, B.C., 1907-1908



moves towards the north, and when the easterly movement is pronounced the other instrument travels to the southward.

Since the publication of these curves the author has succeeded in plotting a continuous daily record of the E-W pendulum from January 1, 1899, to December 31, 1908, a period of ten years, and has also made monthly and yearly tables therefrom.

The following information has been gathered from the ten years' study of this interesting subject:—

The movements of these pendulums demonstrate a tilting of the earth's surface in the direction where the atmospheric pressure is the greatest. For example, when the air pressure is greatest from California north-eastward to the Canadian prairie provinces, and lowest over British Columbia and the adjacent ocean, one pendulum swings towards the east and the other to the south.

These movements are greatest during the stormy months of winter and least in summer, when the changes of air pressure are small throughout the Pacific slope.

These pendulums often commence and continue to swing in a certain direction hours, and sometimes more than a day, before the barometers along the Pacific coast indicate the approach of great cyclonic and anti-cyclonic areas from the ocean.

To arrive at the true connection of these pendulum movements and changes of air pressure, the former must be studied with the weather charts covering areas of from one to two thousand miles in extent, otherwise the local atmospheric conditions may appear to cause a tilting contrary to that indicated by the instruments.

The loading of the Pacific slope during the winter months by heavy rains on the lower lands and vast quantities of snow upon the great mountain ranges of the interior may account for a small proportion of the easterly tilting. The ten years' curves clearly demonstrate, however, that pronounced westerly swings occur when vast areas of high barometric pressure approach from the westward.

The loading effect upon the coast due to a tidal action is only noticeable upon the records when little differences of air pressure prevail and during great tidal ranges. The remarkable absence of the tidal action is probably due to these instruments being situated upon the south end of Vancouver Island, where a fairly equal rise and fall of the tide occurs upon both sides of the island at about the same time.

The diurnal range of a westerly swing in the morning and an eastward one in the evening is most marked during fine weather, and least when the weather is overcast.

In order to obtain similar observations at other portions of the Pacific slope the author is pleased to state that Mr. T. S. Shearman, our meteorological observer at Vancouver, has at his own expense constructed two horizontal pendulums, and will shortly furnish daily readings from these instruments.

Through the courtesy of the Chief Engineer of the Grand Trunk Pacific Company, of Prince Rupert, another instrument will shortly be installed there, and daily observations taken.

Mr. T. R. Stockett, manager of a large coal mine at Nanaimo, has kindly consented to allow the author to install two instruments, one upon the surface and another 1200 feet below in this mine, and will furnish daily readings from them.

These instruments the author is now personally constructing, and hopes to have all in operation before the great winter movements commence.

In conclusion it is respectfully suggested that this subject be more fully studied by a special committee both upon this continent and at all stations where the Milne seismographs are installed.

Section B.—CHEMISTRY.

President of the Section:
Professor H. E. Armstrong, Ph.D., LL.D., F.R.S.

THURSDAY, AUGUST 26.

The President delivered the following Address:—

It is recorded that after saying, on a certain occasion, 'I shall not often give arguments but frequently opinions—I trust, with courtesy and propriety, etc.,' a professor of world-wide reputation remarked, 'A man's opinions, look you, are generally of much more value than his arguments. These last are made by his brain and perhaps he does not believe the proposition they tend to prove—as is often the case with paid lawyers; but opinions are formed by our whole nature—brain, heart, instinct, brute life, everything all our experience has shaped for us by contact with the whole circle of our being.'

Of his many charming utterances at the breakfast table, I would select this as one of the most noteworthy and just withal. Chemists especially need to take both opinions and feelings as well as arguments into account to appreciate more fully, perhaps, than is now customary the need of cultivating and giving expression to that state of mind which is the main qualification of the expert—the state of mind which, let me insist, in the case of the chemist, is only to be acquired by constantly associating with and constantly handling substances in being and in the making, by constantly striving to become acquainted with their innermost nature and idiosyncrasies. It is safe to say that much of the subject-matter of our science cannot yet be quantified and probably never will be; it is even easy to overrate the value of quantitative measurements, as the processes studied, more often than not, are involved operations that can only with difficulty, if at all, be resolved into their factors.

After an interval only a year short of a quarter of a century, it is my privilege again to occupy the chair of this Section and that, too, under conditions of special significance. The British Association has never before sought to carry the banner of science so far west into British Dominions—never before was it so clear that the progress of humanity is linked with the progress of science by an indissoluble bond: science defined in a word being *knowledge;* yet not mere word nor mere lip knowledge but systematised established knowledge—not assumed knowledge, although hypothesis often serves to guide inquiry and truth is arrived at only gradually and slowly by a series of rough approximations. Moreover, science is true knowledge *of every kind* there is too often a tendency to give a narrow interpretation

of the word. One reason probably why the word does not produce any proper effect upon the average British ear is that it is not an English term but a mere adaptation from the Latin—a language which apparently cannot be engrafted upon our Saxon tissues; although, perhaps, it may be that we have so little feeling for it because we have been allowed to learn so little else in our higher schools: monotony of diet ever favours diminutive growth. Germans, I always feel, enjoy a great advantage over us in possessing the popular word *Wissenschaft*—in calling science the *business of knowing*, the *business of gaining wisdom*, of *being wise*.

Coming as we do to Canada to advocate such a cause: to direct attention to the principles on which alone such a business can be learnt and conducted with profit—surely we may count on meeting with the support of the public at large; it is this we desire and claim—not merely the support of a few specialists; moreover, we do not ask for it in any way as a favour but practically demand it as a right—in no way, however, on personal grounds or with any display of arrogance but because we are persuaded that our message is of such infinite importance to the well-being of the community that it is our clear duty to make it of avail. Here it is that opinion, not argument, must count: the language of science is and must remain, in many ways, a strange one to the public; we must therefore ask that they entrust us with their confidence and allow themselves to be guided by the experience we have gained. We must be as the prophets of old: regardless of consequences, we must insist on the overthrow of the idols which a narrow priesthood still attempts to force upon society. We need always remember that, as my good friend the Professor expresses it—'Man is an idolater or symbol-worshipper by nature, which, of course, is no fault of his; but sooner or later all his local and temporary symbols must be ground to powder, like the golden calf—word-images as well as metal and wooden ones.' It is, as he says, 'Rough work, Iconoclasm—but the only way to get at Truth.'

Naturally I am constrained, on the present occasion, to take stock of the position of our science—to draw a comparison between the condition of affairs chemical when we met in Aberdeen in 1885 and their present state. No like period of human history has been more fruitful of advance; at the same time, no period illustrates more clearly the difficulties that lie in the path of progress—because of the innate conservatism proper to human nature.

It was my privilege in 1885 to discuss a variety of problems which then seemed to be of special importance in relation to the subject of Chemical Change, our main province of study. I find the same problems dominant now—still unsolved but yet nearer solution. The history of progress, of discovery, during the intervening period is wonderfully rich in incident—how rich perhaps few realise, as it is obscured by a mass of blinding detail. If I attempt to bring some of the scattered threads together and in so doing dare to paint a picture which here and there may be startling in its outlines and implications; if I venture to follow the example set by one who has appeared as an autocrat as well as a professor and sometimes give my naked opinions: it will, I trust, be understood that I do so conscious that the sketch I am presenting must be full of the faults to which all such attempts are subject.

In my previous address two very different topics were considered—the Educational Outlook and the Theory of Chemical Change. In dealing with the former, I drew special attention to the need of creating an atmosphere of research in our colleges—then to the faulty curriculum of our schools and the need of introducing reforms into practically every branch of education, especially medical education. In the interval, considerable progress has been made by way of forming plans for the future, even a foundation stone

or two has been put in place, although scarcely 'well and truly laid'—but the actual buildings are barely marked out. In point of fact, the needs to which I called attention in 1885 are our present and now most urgent needs. But of this more subsequently.

In discussing chemical action, I commented on our failure to arrive at any understanding as to the conditions which determine the occurrence of chemical change—a failure all the more remarkable in view of the clearness of Faraday's early teaching. Basing my remarks on the thesis which he propounded in 1834 that the forces termed electricity and chemical affinity are one and the same, I discussed current views on electrolysis and arrived at a conclusion entirely adverse to the explanation put forward by Clausius that the conductivity of electrolytes was conditioned by the presence of a small proportion of separate ions; this was at a time when the views of Arrhenius were not yet spread abroad, although they had been communicated to the Swedish Academy; I knew of them only from Ostwald. In justice to the attitude of complete antagonism which I have always maintained towards the speculations of the Arrhenius-Ostwald school, I may point out here that in drawing attention to the views expressed by Arrhenius and Ostwald as to the correlation of chemical with electrolytic activity (and I was the first English writer who called attention to them), I took occasion to say: 'There cannot be a doubt that these investigations are of the very highest importance.' In the interval, Ostwald has charged his test-tubes with ink instead of with chemical agents and by means of a too facile pen has enticed chemists the world over into becoming adherents of the cult of ionic dissociation—a cult the advance of which may well be ranked with that of Christian science, so implicit has been the faith of its adherents in the doctrines laid down for them, so extreme and narrow the views of its advocates. At last, however, the criticism which has been far too long delayed is being brought to bear and the absurdity of not a few of the propositions which the faith entails is being made evident; it is to be hoped that we shall soon enter on a period in which common sense will prevail once more; that ere long an agreement will be arrived at both as to the nature of chemical change in general and as to the conditions which determine it. The lesson we shall have learnt will be one of no slight import, if it but teach us the ever-present need of questioning our grounds of belief, if it serve to bring home to us the danger of uncontrolled literary propagandism in science, if it but cause us always to be on our guard against the intrusion of authority and of dogmatism into our speculations.

Before attempting to deal with any of the problems which concerned us at Aberdeen I will first briefly pass the more salient features of advance in review. Few probably are aware how extraordinary is the command we now have of our subject. In 1885, in defending the tendency of chemists to devote themselves to the chemistry of carbon, I could speak of the great outcome of their labours as being the establishment of the doctrine of structure. Everything that has happened in the interval is in support of this contention. It is interesting that in a recent lecture[1] on the Physical Aspect of the Atomic Theory, the most prominent living exponent of physical theories has given a not unwelcome recognition of our right-mindedness in saying: 'As time goes on it becomes increasingly difficult to resist the direct evidence for the simple view that, in many cases, chemical combination is not so much a fusion or intermingling of the combining atomic structures as rather an arrangement of them alongside one another under steady cohesive affinity, the properties of each being

[1] The Wilde Lecture, 1908. By Professor Larmor, Sec. R.S., *Manchester Literary and Philosophical Society Memoirs.*

somewhat modified, though not essentially, by the attachment of the others; and that the space formulæ of chemistry have more than analogical significance.' And again in the following passage, in which a far-reaching confession is made: 'The aim of structural chemistry must go much deeper (than dynamical methods of treatment); and we have found it difficult, on the physical evidence, to gainsay the conclusion that the molecular architecture represented by stereo-chemical formulæ has a significance which passes beyond merely analogical representation and that our dynamical views must so far as possible be adapted to it.' The remark made by Helmholtz in one of his letters, 'that organic chemistry progresses steadily but in a manner which, from the physical standpoint, appears not to be quite rational,' must be regarded as little more than a confession that he was out of his depth. When properly understood, nothing could be more rational and logical than the way in which our theory of structure has been gradually built up on an impregnable basis of fact, with the aid of the very simple conceptions of valency postulated by Frankland and Kekulé. Our security lies in the fact that the postulates of our theory have been tested in an almost infinite variety of cases and never found wanting; this is not to say they are applicable in all cases, but merely that whenever we are in a position to apply them we can do so without hesitation. Larmor refers to the habit of physicists of taking comfort in Helmholtz's remark; it will be well if instead they make themselves acquainted with our methods and with the results we have won, with a minimum of speculative effort, by the cultivation of an instinct or sense of feeling which experience shows to be an effective guide to action. Now that physical inquiry is largely chemical, now that physicists are regular excursionists into our territory, it is essential that our methods and our criteria should be understood by them. I make this remark advisedly, as it appears to me that, of late years, while affecting almost to dictate a policy to us, physicists have taken less and less pains to make themselves acquainted with the subject-matter of chemistry, especially with our methods of arriving at the root-conceptions of structure and of properties as conditioned by structure. It is a serious matter that chemistry should be so neglected by physicists and that the votaries of the two sciences should be brought so little into communion.

The central luminary of our system, let me insist, is the element carbon. The constancy of this element—the firmness of its affections and affinities—distinguishes it from all others. It is only when its attributes are understood that it is possible to frame any proper picture of the possibilities which lie before us, of the place of our science in the Cosmos. As Longfellow sings of the sea in his poem 'The Secret of the Sea,' 'Only those who brave its dangers comprehend its mystery'—only those who are truly conversant with the root conceptions of organic chemistry are in a position to attempt the interpretation of the problems of our science as a whole or even to understand the framework upon which it is built up. And yet we continue to withhold the knowledge of the properties of carbon from students until a late period of their development; indeed, when I insisted recently that organic and inorganic chemistry should be taught as one subject to medical students,[1] I was told that it could not be; that the attempt had been made with disastrous consequences. I trust that ere long the futility of such an attitude will be generally realised.

It is remarkable how much our conceptions are now guided by geometrical considerations. The development by van't Hoff of the Pasteur hypothesis of geometrical asymmetry has been attended with far-reaching

[1] 'The Reform of the Medical Curriculum.'—*Science Progress*, January and April 1907.

consequences during the period under review, the completeness with which the fundamental properties of the carbon atom are symbolised by a regular tetrahedron being altogether astounding.

Our present conception is that the carbon atom has tetrahedral properties in the sense that it has four affinities which operate practically in the direction of the four radii proceeding from the centre towards the four solid angles of a regular tetrahedron.

More than analogical significance—to use Larmor's expression—must be accorded to this symbol on account of its remarkable accordance with the facts generally, whether derived from the study of asymmetric optically active substances or from observation of the activity of ring structures of various degrees of complexity. Nothing is more surprising than the completeness with which the vast array of facts included in organic chemistry may be ordered by reference to the tetrahedral model. In the future, when our civilisation is gone the way of all civilisations and strangers dig on the sites of our ruined cities for signs of our life, they will find the tetrahedron and the benzene hexagon among the mystic symbols which they have difficulty in interpreting; if, like the ancient Egyptians, we made our tombs records of our wisdom, such symbols would long since have acquired sacred significance and probably the public would have learnt to regard them with awe and to respect them as totems. Chemists might at least wear them on aprons in imitation of the Freemasons; perhaps no two other symbols have so great a significance—they reach into life itself.

It would seem that carbon has properties which are altogether special, the influence which it exercises upon other elements in depriving them of their activity is so remarkable. In their recent discussion of the relation of crystalline form to structure, in which valency is represented as a function of the volume sphere of influence exercised by an element, Barlow and Pope arrive at the remarkable conclusion that carbon is probably the only element the atom of which has a volume sphere of influence four times that of the hydrogen atom; although it combines with four atoms of hydrogen, silicon apparently has only half the volume sphere of influence of carbon. This may, in a measure, account for the very great dissimilarity in behaviour of the two elements, which is most pronounced in their oxides, the single atom of carbon all but dominating two atoms of oxygen in carbon dioxide (which is consequently gaseous), whilst the atom of silicon in silicon dioxide in no way eclipses the two atoms with which it is associated but leaves both charged with residual affinity which enables them to form complex collocations of remarkable fixity in the fire. At bottom the differences between organic and inorganic nature are to be regarded as very largely the expression of this difference. Ropes of sand are proverbially treacherous: yet without sand, if silica had been a gaseous substance, our world might have worn a strangely different aspect.[1]

[1] The solid model of silica which Barlow and Pope have constructed has very remarkable attributes, in that the oxygen atoms appear to be uniformly related and in intercommunication throughout its mass: so that a mass of silica, whatever its size, may almost be regarded as a single molecular complex. A similar view may be taken of plastic metals such as those of the platinum group, gold, silver and copper. Whether when rendered brittle by association with small amounts of impurity these are resolved into simpler molecular complexes or whether the molecules merely become separated by substances which promote discontinuity and brittleness, it is impossible to say at present. The cause of hardness in mineral materials is, however, a question of no slight interest and importance. The property is strikingly exemplified in the diamond. It is difficult to understand the intense hardness of this material, on the assumption that the diamond is composed of paraffinoid carbon—that is to say, carbon with all its affinities satisfied. At present we appear to have no clue to the manner in which affinity acts in promoting the formation of such solids. But it is obvious that all solids are possessed of some degree of 'surface affinity,' as

The mineral world apparently owes its rigidity to the fact that the metals and certain other elements are so imperfectly capable of dominating oxygen that oxides generally polymerise with great readiness, giving rise to substances which do not even fuse easily. The organic, on the other hand, appears to be plastic by reason of the close approach to neutrality which is conditioned by association with carbon.

Nothing is more striking than the remarkable diversity of properties manifest both in the materials which at present we are content to call elements and in the compounds formed by their interaction; the range of variation met with in the case of the compounds of carbon with hydrogen and oxygen alone is almost infinite. We are almost compelled to attribute this diversity more to differences in the complexity and structure of the molecules than to differences in their material composition. The chemist, of necessity, must be a dreamer, knowing as he does that things are not as they seem to be. But this is not sufficiently remembered; indeed, students are systematically trained up in an atmosphere of pretence. The beginner is allowed to regard *elementary oxygen*, for example, as a colourless gas which is generally harmless until things are presented to it in a more or less heated condition, whereat it takes umbrage and burns them up. He would regard elementary carbon as a soft black substance which if smeared on the face of the white man makes him look like a nigger, were it not that he also learns that at times it is the hardest and whitest substance known; of organic chemistry, which alone can give him honest ideas of carbon, he is not allowed to hear as I have said. The sting of awakening conscience is salved by the introduction of a long Greek word when he is told that the two substances, soot and diamond, are *allotropic* forms of the element carbon; nevertheless he regards them both as elementary carbon. Gradually, perhaps, he awakens to a sense of the wrong that he has suffered at the hands of his teachers, as he realises that from no one substance can he gather what the properties of an element are, that after all the elementary substance is but an ideal—in other words, a mere concept. If appreciative, he then learns to think of the blandness of water, the sweetness of sugar, the sourness of vinegar, the causticity of soda, indeed of every distinctive property of every known oxygen compound as more or less a property of, more or less conditioned by, the element oxygen: he is brought back, in fact, to the position from which Lavoisier started, as he realises that the oxygen *gas* which he inhales is not elementary oxygen; he can then perhaps appreciate the wonderful acumen which this greatest of chemical philosophers displayed when he wrote: 'Nous avons donné à la base de la portion respirable de l'air le nom d'oxygène en le derivant de deux mots grecs ὀξύς, acide, γείνομαι, j'engendre, parce qu'en effet une des propriétés les plus générales de cette base est de former des acides en se combinant avec la plupart des substances. Nous appellerons donc gaz oxygène la réunion de cette base avec le calorique.' We have allowed a century to pass without recognising the wonderfully accurate powers of prevision displayed by Lavoisier; what is worse, we have been so far led astray that instead of regarding oxygen as the characteristic and attractive element in acids, hydrogen has been allowed to usurp the position: the extent to which the cult of the hydrogen ion now dominates the text-books

they not only grow when placed in solutions but determine the separation of solids from solutions at a degree of saturation which is often considerably below that at which the solution is actually saturated with the substance; and such surface affinity, moreover, is selective, as the determinative effect is exercised only upon the substance itself or substances isomorphous with it—although exception must be made in favour of water, which all surfaces appear to attract. Sir James Dewar's observations on the condensation of gases by charcoal at low temperatures afford most striking illustrations of surface affinity.

is well known; in days to come, when the history of our times is written, it will be referred to as a remarkable example of chemical shortsightedness.

Names are needed for the elements which would serve to distinguish the ideal elementary substances from the forms in which they are known to us. No more appropriate name than oxygen could possibly be selected for the fundamental material; if the *gen* terminal could be applied to elementary materials generally, it would be an advantage; it would not be easy, however, if this were done, to devise an appropriate separate name applicable to the active constituent of air.[1]

In 1885 I closed my address with a reference to the structure of the

[1] In naming the inert gas in air, which he ultimately termed *azotic gas*, having proposed the name *azote* for the element, Lavoisier had in view as alternatives the terms *alcaligen* and *nitrogen*. As there was no proof that the element was a constituent of alkalies other than ammonia, he rejected the former name on the ground that it might convey too broad an impression; in course of time the latter is become the popular name, except in France, where motives of piety have prevailed; but the French practice has been justified by the universal use of the term *azo* in connexion with many nitrogen derivatives.

Had Lavoisier realised that the alkalies and basic oxides generally owe their basicity to oxygen as much as acids and acidic oxides generally owe their acidity to oxygen—the one being oxygen tempered by metal, the other oxygen tempered by non-metal—as the number of basic oxides far outweighs the number of acidic oxides, he might well have chosen the name alcaligen rather than oxygen. The choice he made was a particularly happy one and striking evidence of his genius and sense of euphony—for oxygen is *par excellence* the acid-forming element and is most truly called *sour-stuff*, the stuff of which sour things are made: whatever the properties of the initial oxide of a series, as the proportion of oxygen is increased, the acidic qualities are invariably strengthened.

The choice of a terminal connoting the elementary radicles which would be applicable generally and also acceptable is very difficult. If usage do not forbid change, probably our ears will decline to allow us to be systematic. The terminal *gen* is not applicable to many present names. In the interest of euphony, exception may be taken to the adoption of *ion* as a final syllable. In English ears most of the words with this ending have an ugly sound if pronounced so as to make it significant; moreover, our object is to secure a term which is applicable to the elementary material, whatever its state; the term ion is suggestive of a particular state—a state of chemical activity; and at present there is no agreement as to the nature of an ion. The terms atom, radicle (simple and compound), ion and molecule now all have their separate meaning and value and are indispensable.

The only terminal which seems in any way likely to be generally satisfactory in use is the terminal *yl*, which is already applied to organic radicles; its use might well be extended to radicles generally.

I may add here that it is unfortunate that certain disturbers of the peace have advocated of late a reversion to the spelling *radical*, mainly on the ground that the term is of French origin and was thus spelt originally. But there is no reason to give a French spelling to a word when it becomes English; and the genius of our language is against the proposal, apart from the fact that it introduces unnecessary confusion. We make clear distinction between *principal* and *principle*; it is most desirable, in like manner, to distinguish between *radical* and *radicle;* the latter is in harmony with *particle* and *participle* and being suggestive of a rootlet, it is eminently significant. *Radical* is almost misleading, as a radical in these days is apparently one whose tendency is to go to extremes while contemplating the surface only instead of going to the root of things.

It would be to the advantage of students also if we were far more systematic in our use of formulæ as well as in matters of nomenclature. At present no proper distinction is made between empirical and molecular formulæ in the case of the elements. Notwithstanding that we acknowledge our indebtedness to Avogadro and to Canizzaro his prophet, it is still not unusual to find gaseous hydrogen represented by the symbol H and gaseous oxygen by the symbol O; the text-books generally pay little heed to such matters. We are far too careless of consequences in our teaching and do not sufficiently appreciate the value of system and ritual. If it were made the practice to represent molecular formulæ in some special manner—by Clarendon or thick type, for example—attention

elements which implied that their behaviour was that of compound substances; the feeling that this is the case has long been general among chemists. Our present attitude towards this problem is a curious one and not altogether satisfactory—it is impossible to deny that we have somewhat lost sense of proportion, even if our methods have not savoured of the unscientific. The discovery of radium appears to have upset our balance—we have been carried away by the altogether mysterious and unprecedented behaviour of this weird and wondrous substance. But may we not ask: Is radium an element? Has it not been too generally, too hastily assumed that it is? Little as we know of it, does not its behaviour straightway outclass it as an element? Surely it does! Is not the established fact that an emanation proceeds from it, which in turn decomposes and gives rise to helium, a proof of its compound nature? Again, is the evidence of such a character as to justify us in asserting that uranium is the parent of radium? If it be such, must not uranium also disappear from the list of elements; must it not indeed be removed on the ground that it gives rise to uranium$-x$ without any reference to its supposed relationship to radium?

The answers given to such questions must depend on our definition of an element. At present we seem to be without one.

The conception that the break-down of radium is spontaneous and apart from all external impulse or control is also one which should be received with caution. There is reason to suppose that in all ordinary cases in which compounds undergo decomposition spontaneously, the decomposition is conditioned by an impurity; the effect, moreover, is usually cumulative. This is true of highly explosive substances, such as chloride of nitrogen and guncotton, for example. It might be supposed that something similar would happen in the case of radium—but apparently such is not the case; it is assumed that occasionally a molecule explodes spontaneously, not only without being incited thereto but also without in any way affecting its neighbours.

The alternative explanation that radium in some way acts as a receiver,

would then be called to the fact that in the majority of cases the substances used are of unknown molecular composition.

If a student see sodium chloride always represented as NaCl or, what is worse, in accordance with a growing evil custom, learn to speak of it as *En-ay-cee-el*, it becomes difficult to persuade him that probably such a formula is a misleading expression—at all events, in no way the expression of known fact. Nothing could be worse than the tendency which is coming over us to speak of substances in terms of their formulæ instead of by name. It is difficult to understand what can be gained by referring, for example, to carbon dioxide as *Cee-oh-too*. Such vulgarisms and also the substitution of formulæ for written or printed names should be discountenanced on every possible occasion.

The reproach is not unfrequently levelled at us that scientific workers lack literary style and that they do not take sufficient pains in describing their work clearly and concisely—too often with justice. At all events, as the complaint has been made from the Chair at several recent anniversary meetings of the Royal Society, some notice should be taken of it.[1]

Solecisms are only too abundant in our literature. It is sheer carelessness to speak of compounds 'adding' this or that, instead of saying that they combine with it; the statement that a substance 'analyses' is inexcusable. The use of such expressions is proof that no thought has been exercised in writing.

An old writer has expressed an eternal truth in saying: 'All soche Authors as be fullest of good matter and right judgement in doctrine be likewise always most proper in wordes, most apte in sentence, most plain and pure in uttering the same.'

---

[1] Complaint is made even in Germany. Compare von Lippmann: 'Ueber den Stil in den deutschen chemischen Zeitschriften,' *Chemiker-Zeitung*, May 6, 1909, p. 489.

transforming energy from some external source to which ordinary substances fail to respond and being thereby stimulated to decompose, is at present out of favour, although perhaps more in accordance with its peculiar behaviour.[1]

The liberation of helium as a product of radio-active change is in itself a significant fact, in view of the possibility that helium may be an element of intense activity. Nothing in connexion with the problem is more surprising, however, than the apparent production, in course of time, of a whole series of degradation products which differ greatly in stability—such behaviour is entirely without precedent and not at all becoming in elements.

No such remarkable and inspiring problem has ever before been offered for solution. We can only wonder at the results and admire the genius which some have displayed in interpreting them, Rutherford in particular. Yet outsiders may well hold judgment in suspense for the present: whilst it is permitted to workers to make use of hypothesis in every possible way in extending inquiry, the public are in no wise called upon to accept such hypothesis as fact.

But apart from the suggestion that elements may give rise to others spontaneously, we have been entertained of late with stories of elements being converted into others under the influence of the energy let loose by the breakdown of radium. There is reason, however, to suppose that the powers of radium may have been greatly overpainted; energy of almost any degree of intensity in the form of high tension electricity is now at our disposal and the effect which radium produces on living tissues, glass, &c., is of the same character as that effected by the Röntgen ray discharge, the only difference being that the effect is produced somewhat more rapidly; it is not to be imagined, therefore, that the discovery of radium has put any very novel intensity of power into our hands.

It is right that the public should understand that the statements published have been based on preliminary observations which lack verification, such as would never have been divulged in days gone by when a sterner sense of duty pervaded our ranks. Until the elementary nature of radium has been placed beyond question, we must hold judgment in suspense even as to the possibility of 'elements' undergoing decomposition 'spontaneously'; at present, the possibility of elements being decomposed or transmuted by means of radium need not be entertained until evidence is forthcoming of a more convincing character than that with which we have been favoured.

We have been living in a time of sensational discovery—in a period when advertisement is favoured and the desire for notoriety rampant. Unhappily that caution which appeared to be regarded as a priceless

[1] I may here put on record the opinion Lord Kelvin expressed on this question in a letter to me dated September 13, 1906:—

'Ever since, nearly four years ago, we heard of the hundred calories per hour given out by radium, I have had on my mind the question of some possible mechanism such as that which you suggest by which energy from surrounding matter (far or near) could automatically come into radium to supply the energy of the heat which it gives out. The more I think of the question the less I see of that possibility. At present I can see nothing else than that the energy given out is taken from a previously existing store of potential energy of repulsive force between separable constituents of radium.

'The "disintegration of the radium atom" is wantonly nonsensical. It is nonsense very misleading and mystifying to the general public, because, if what is at present called radium can be broken into parts, it is not an atom.

'"Energy of an atom" implies a thorough misunderstanding of the meaning of the word energy, which is capacity for doing work.

'I admire most sincerely and highly the energy of the workers in Radioactivity and the splendid experimental results which they have already got by resourceful and inventive experimental skill and laborious devotion. I feel sure that as things are going on we shall rapidly learn more and more of the real truth about radium.'

prerogative of the scientific worker in the earlier part of the last century, of which Faraday was so pre-eminent an exponent, is no longer our recognised watchword. I fear I am one of those who are old-fashioned enough to lament the way in which our claim to be safe and honest guides of public opinion is being endangered—who lament the manner in which the reputation of scientific workers is likely to be besmirched if we do not see the evil of our ways and mend them. It is impossible to avoid noticing how the cancer grows—how the example is spreading among the younger men and loose habits of work and thought are being engendered. I know that not a few who have laboured steadfastly and seriously in an old-fashioned, exact and painstaking way, have been deeply hurt by the manner in which their efforts fail to meet with encouragement whilst those who have thrown caution to the winds are favoured; the feeling is beginning to arise that only sensational discovery is appreciated by the public. We need to return to the healthy times when fearless and frank criticism of all work was deemed desirable. We cannot substantiate the claims that are made on behalf of science unless our own attitude be above reproach—unless we are both logical and philosophical—unless we remain the sternest advocates of truth in its most rigid form.

I pass to the consideration of the classification of the elements. The recognition of certain properties, the association of certain ideals with the several elements, is a necessary step in classifying the elements in accordance with Mendelejeff's great generalisation—or rather it may be said to be both involved in and an outcome of Mendelejeff's conception.

Until recently our difficulty was to understand the relationship of the metallic and the non-metallic elements; now we are confronted with another problem—that of the existence of inert 'paraffinoid' elements. It is commonly assumed that these are monatomic but the evidence on which this assumption is based is absolutely unconvincing and would be generally admitted to be so were we in the habit of looking before we leapt to conclusions. Assuming that the elements are compounds, the formation of inert compounds does not appear to be out of place, in view of the existence of practically inert hydrocarbons. But on the other hand, in view of the properties of nitrogen, which is one of the most active of substances in the monatomic state, although an inert gas in the diatomic condition, it may well be that the inertness of helium and the other members of the argon group is also simulated. Sir James Dewar's observations have shown that helium and charcoal have no inconsiderable affinity at the boiling point of the former, which is within five degrees of the absolute zero, the molecular heat of absorption (apart from that due to liquefaction) of helium at that temperature being apparently as high as about sixty calories. The proof he has given that helium alone does not convey an electric discharge is also of significance since the passage of a discharge through it under ordinary conditions is an indication that it can be included with other substances in a conducting system. Such evidence as there is therefore points to the elements under discussion being different from the others only in the degree of stability of their molecules.

Of late years the difficulty of classifying the elements has been increased rather than diminished, not merely because of the discovery of the inert gases but also on account of the apparent impossibility of ordering the position of an element such as tellurium in accordance with its atomic weight. There appears to be little room left for doubt that the value cannot be far removed from that of iodine; it should be considerably lower. It may be pointed out that the accepted value of selenium is closer to that of bromine than would be expected if a relationship were maintained corresponding to that between chlorine and sulphur. It would seem that Mendelejeff's original conception of the elements as a simple series in which the properties are

periodic functions of the atomic weights must be abandoned in favour of some more comprehensive scheme. From the chemist's point of view, it is impossible to abandon the guiding principle underlying the arrangement in family groups, which dates back to Dumas; perhaps insufficient attention has been paid in the past to the maintenance of this principle.

Taking this principle into account it is impossible to arrange a long series of elements such as the rare earths continuously in order of atomic weight, as they would be brought into every family in the table by such a procedure; the difficulty has been got over by Brauner, who has proposed to arrange a large number of the rare earths in a single vertical series under barium. Biltz has made a similar proposal.

The principle had been advocated by me previously in an article written for the 'Encyclopædia Britannica.'[1]

In the arrangement I have proposed, it is not only assumed that there may be as many as sixteen vertical series of elements of which the elements from hydrogen to oxygen are initial terms, some series being at present unrepresented, it is also suggested that groups of elements occur in perhaps four of these series, numbers 4, 8, 12 and 16, the largest being that of the so-called rare earths in series 8.

The principle which is assumed to be in operation is that which is so clearly manifest in the case of hydrocarbons: successive vertical series of elements correspond to successive isologous series of homologous hydrocarbons. In the case of the hydrocarbons, the passage from one isologous series to another often takes place from a term several places removed from the origin of the series—for example, from benzene, C_6H_6, which may be regarded as primarily a derivative of hexane, to naphthalene, $C_{10}H_8$, which is not an immediate derivative of benzene but of butylbenzene. It is conceivable that at the genesis of the elements a process was at work corresponding to that by which a hydrocarbon such as naphthalene is derived from benzene and by which the former then serves in turn as the point of departure for more complex hydrocarbons of other series. There is no reason, from this point of view, why progression should not take place along a particular line and that terms should exist in a series through which this line passes but below it—for example, that antimony and iodine may bear a direct linear relationship but that tellurium, instead of being the element in the progression series in the oxygen group, is a homologue of greater weight. The same view may be taken of selenium. In this way, it would be possible to maintain selenium and tellurium in the oxygen-sulphur series, from which they cannot well be separated, whilst retaining Mendelejeff's conception of a genetic relationship along the series. The only departure involved is in assuming that instead of forming a single linear series ascending regularly in spiral progression—a series which can, as it were, be strung on a single spirally wound cord—the elements closely simulate a series of homologous isologous hydrocarbons. From this point of view, it is easy also to understand that some vertical series are unrepresented.

In discussing the chief attributes of the elements none is so difficult to deal with as that of valency, using the term in the broadest possible sense, not merely as indicative of the number of units of affinity but as including the, at present, all but incomprehensible problems of residual affinity and elementary character. I discussed the subject somewhat fully in my former address, dwelling especially on the properties of negative elements and the power such elements have of acting as linking agents; this view has met with ample confirmation in the interval and will, I believe, be found to be of wide application in the future. I have already referred to the manner in which it is exemplified by silica.

[1] Cf. *Roy. Soc. Proc.*, 1902, vol. lxx. pp. 86-94.

The greatest advance in the discussion of the problems of valency in recent years is that made by Barlow and Pope, as their method of treatment is one which applies to solid substances—the correlation of structure with crystalline form which it effects promises to be of far-reaching importance.

Apart from hydrogen, carbon is the one element of certain character, acting always as a tetrad—its affinities may be only incompletely satisfied but they are always exercised, it may be supposed, even in ethenoid and similar compounds; carbon monoxide apparently is the only exception to this rule, its relative inactivity being one of the most puzzling enigmas of our science, especially as the oxide becomes one of the most active of known substances when only two atoms of hydrogen are added to it. Most other elements (non-metallic) seem to vary in valency, the valency beyond a certain minimum being dependent on the nature of the association. Of late years, attention has been drawn in particular to the quadrivalency of oxygen in many of its compounds.

The quadrivalency of sulphur in substances such as trimethylsulphonium iodide, Me_3SI, having been proved to demonstration by the production of optically active compounds of this type (Pope and Peachy), it can no longer be supposed that in such cases we are dealing with compounds in which the negative constituents of the parent molecules are conjoined, *e.g.*, $MeI:SMe_2$. And yet we must contemplate the existence of such compounds as possible—in the case of nitrogen, for example, as ammonia must be supposed to form the compound $NH_3:OH_2$ in preference to the hydroxide $NH_4\cdot OH$, the latter being only a very minor constituent, the former the major component of the aqueous solution of the gas; hydrogen chloride, on the other hand, appears to afford only one product with ammonia, viz., $NH_4\cdot Cl$. The existence of such differences is clear proof in the case of the non-metallic elements other than carbon that valency is not merely a variable but also a reciprocal or dependent function.

There is no reason to suppose that hydrogen ever acts otherwise than as a simple monad; and the behaviour of the alkalies and alkaline earths in salts would seem to justify the conclusion that they have no tendency to vary in valency, were it not for the existence of well-defined non-volatile hydrides of these metals which are clearly substances of some degree of molecular complexity. Such compounds are illustrations of the difficulties which surround the subject. It has long been clear that the exhibition of the higher valency by an element is a process of a different order from that manifest when it exerts only its lower proper valency measured in terms of positive radicles such as H or C_nH_{2n+1} radicles. What that difference is we are not able at present to decide—carbon (together with silicon) differs from almost all other elements especially in combining with hydrogen and analogous radicles to the extent of its maximum valency.

The proposition I made in 1888 (*Phil. Mag.*, Series V., 25, 21) that the valency lines should, in some cases, be represented as passing through the atom, so that each is capable of acting in two directions, is the only consistent mode of expressing varying valency which has been devised, the only one, moreover, by which attention is drawn to the great difference.

In many cases probably there has been a tendency to exaggerate the valency value—in the case of chlorine, for example, in assuming that it functions as a heptad in the perchlorates. In this and many other instances, it suffices to assume that the chlorine and oxygen atoms are united in a closed ring, the chlorine functioning as a triad. Some such explanation will doubtless be given of the structure of the metallic ammonias and similar compounds. The co-ordination values introduced by Werner serve merely to establish certain empirical relationships and are only useful for the purposes of classification. The perhaps more rational plan of dealing with such compounds suggested by Abegg has a similar value.

It is to the advantage of the hypothesis formulated by Barlow and Pope that the elements are represented as of constant valency in so far as their relative volume spheres of influence are concerned—the compound in which the higher valency is manifest being derived from that of lower valency by the opening out of the close packed arrangement and the insertion of certain new elements; but the fact that in such cases the volume is altered not in one direction alone in the crystalline structure but proportionately in all directions would seem to show that the volume sphere of atomic influence does actually change; the change is one, however, which affects all the atoms in the complex proportionately.

At present, unfortunately, our methods of treating the problems of valency are such that we cannot in any way give expression to the energy side of the phenomena.

Of late there has been talk of electrons in this connexion but what is said is little more than superficial paraphrase, in the advanced scientific slang of the day, of the ideas which have long been current. When, following Odling, we represent valency by dashes written after the elementary symbol, we give clear expression by means of a simple convention to certain ideas that are well understood by all among us who are versed in the facts; to speak of electrons and use dots instead of dashes may serve to mislead the unwary, who hang on the lips of authority, into a belief that we have arrived at an explanation of the phenomena, but those who know that we have reached only the let-it-be-granted stage, who feel that the electron is possibly but a figment of the imagination,[1] will remain satisfied with a symbolic system which has served us so long and so well as a means of giving simple expression to facts which we do not pretend to explain. Not a few of us who listened to the discussion of the nature of the atom at Leicester could not but feel that the physicists knew nothing of its structure and were wildly waving hands in the air in the endeavour to grasp at an interpretation which would permit of mathematical interpretation being given to the facts. Until the credentials of the electron are placed on a higher plane of practical politics, until they are placed on a practical plane, we may well rest content with our present condition and admit frankly that our knowledge is insufficient to enable us even to venture on an explanation of valency.

In 1885 and again in 1888, I ventured to call in question the interpretation of valency which Helmholtz had given in the Faraday lecture in 1881. On the present occasion, I would insist still more emphatically on the insufficiency of the atomic charge hypothesis; especially that it affords no satisfactory explanation of variable valency and of those fine shades of difference which are manifest, especially in the case of nitrogen, when the radicle attached to the dominant element is varied. In 1885 I discussed this question with reference to the nature of electrolytes and questioned the conclusion Helmholtz arrived at that electrolytes belong to the class of typical compounds the constituents of which are united by atomic affinities, not to the class of molecular aggregates. The opinion I then ventured to give was as follows:—

'The current belief among physicists would appear to be that primarily the dissolved electrolyte—the acid or the salt—is decomposed almost exclusively. We are commonly told that sulphuric acid is added to water to *make it conduct*,

[1] In my opinion the experimental evidence is in no way satisfactory. It appears to me to be desirable that in studying the phenomena of electric discharge in gases, especially in vapours of complex substances, the horrible pitfalls should be taken into account with which the field of work is studded; unless every precaution to secure purity—precautions such as Baker and Dewar have taught us to use—be taken at every step, the conclusions based on all such observations must be open to grave doubt.

but the chemist desires to know why the solution becomes conducting. It may be that in all cases the "typical compound" is the actual electrolyte—*i.e.*, the body decomposed by the electric current—*but the action only takes place when the typical compounds are conjoined and form the molecular aggregate*, for it is an undoubted fact that HCl and H_2SO_4 dissolve in water, forming "hydrates." This production of an "electrolytical system" from dielectrics is, I venture to think, *the* important question for chemists to consider. I do not believe that we shall be able to state the exact conditions under which chemical change will take place until a satisfactory solution has been found.'

The position is not very different now. Although the propagation of the ionic dissociation cult has assumed the form of a fine art, we are still as far as ever from agreement as to the nature of chemical change; the speculation has not helped us in the least to clarify our ideas; at most we learn that interactions are between ions, and even these, as a rule, are supposed to remain apart until they enter into the solid state. Throughout all these years I have never varied my opinion that the dissociation hypothesis is incompatible with the facts. On more than one occasion I have stated definite reasons which induce me to deny its usefulness[1] and these arguments have never been met; in fact, there has been little but a conspiracy of silence on the part of the upholders of the creed.

A large amount of work bearing on the subject has been done, chiefly by H. Brereton Baker. Strangely enough, no proper notice of his results has been taken outside England, and even there the importance of the observations have not been sufficiently appreciated. Perhaps the most remarkable feature in the situation is that Baker himself scarcely seems to be alive to the meaning of the evidence which he has supplied; the attitude which he has displayed in his recent Wilde lecture can only be described as halting. Baker has shown, in case after case, that the occurrence of change is dependent on the presence of moisture, his greatest feat perhaps being the observation that it is possible not only to prepare nitrous anhydride in the solid and liquid states but to volatilise it unchanged if only water be excluded.

I venture to think there is only one point of view from which the problem of chemical change can be approached, that, namely, which we owe to Faraday—to which hitherto justice has in no way been done—on which I dwelt persistently in my previous address: that the forces termed chemical affinity and electricity are one and the same. In every case of chemical change there is a coincident electrical change, an electric flux; on the other hand, every case of electrical change is accompanied by chemical change—some alteration in molecular configuration is effected; the force of chemical affinity is in some way disturbed by a momentary displacement of the molecules when a current passes through a conductor. Such being the case, the conditions determinative of chemical change can only be those which permit of an electric flux. Two substances in apposition do not give rise to a current; at least three are required to determine a slope of potential. Chemical change can only take place if one of the three be an electrolyte. In all cases apparently the chemical change supervenes upon the electrical, the electrolyte being resolved into its ions, one of which at least combines coincidently with the adjacent electrode. Apparently these considerations are applicable to changes generally. And it should be added that, according to this view, the catalyst actually determines the occurrence of change.

The only other criterion which it is necessary to apply in order to decide whether change be possible in any given case is to consider if the

[1] Compare *Chem. Soc. Trans.*, 1895, 1122; *Roy. Soc. Proc.*, 1886, **40**, 268; 1902, **70**, 99; 1903, **72**, 58; 1904, **73**, 537; 1906, **78**, 201; 1907, **79**, 586; 1908, **81**, 80; *Science Progress*, April 1909.

change contemplated be one involving development of energy. It is important to remember also that a change which could not otherwise take place becomes possible when a suitable depolariser is introduced into the circuit.

The evidence that similar considerations apply to the gaseous and the liquid states cannot well be gainsaid. Before framing a theory of chemical change it is therefore necessary to formulate a definition of an electrolyte. It is doubtful if any single substance be an electrolyte; the conductivity of fused salts may well be and probably is conditioned by some admixture. Aqueous solutions of alkalies, acids, and salts without exception are electrolytes. *Everything points to the fact that in such solutions the solvent and solute act reciprocally; the contention that the solute alone is active cannot be justified.* As water is altogether peculiar in its activity as a solvent and is a solvent which gives rise to conducting solutions, an explanation of its efficiency must be sought in its own special and peculiar properties.

Since 1886 this conclusion has been impressed upon me with indisputable force, and I have frequently ascribed the effect produced by the one constituent upon the other in a solution to the residual affinity of the negative elements in the two compounds which act reciprocally. It was only recently, however, that I saw my way to postulate a complete theory which would serve to account for the properties of solutions and that I realised how the reciprocal effect might be produced.

I would substitute for the misleading conception that liquids are comparable in their behaviour with gases the idea that the liquid state is one in which the residual affinity of the negative elements in particular always comes into play and causes the formation of molecular aggregates of various degrees of complexity; moreover, that the alteration in the properties of any given solvent by the dissolution in it of another substance is largely and, in some cases, mainly due to a disturbance of the equilibrium natural to the solvent by an alteration in the proportion in which the several aggregates are present. The alteration in some particular property produced in *a given mass of the solvent* may, from this point of view, be taken as the measure of the activity of a substance, just as the alteration in the pressure of a particular volume is taken as the measure of the alteration produced in a gas. In the case of non-electrolytes, if only a small amount of the solvent be withdrawn by combination with the solute, the alterations may be regarded as almost entirely due to the 'mechanical' interference of the substance introduced, opportunity being given for the simpler, more attractive molecules of the solvent to exist in greater proportion because of the diminution of the chance of reuniting which is conditioned by the presence of practically inert molecules of another kind; if a more or less considerable amount of the solvent become associated with the solute the conditions become more complex but similar considerations apply. From such a point of view a liquid is rendered more active by the addition of any soluble substance. Its vapour pressure is therefore diminished; the internal 'osmotic' stresses are raised; its freezing-point is lowered.

Although it is generally admitted that water is not a uniform substance but a mixture of units of different degrees of molecular complexity, the degree of complexity and the variety of forms is probably underestimated and little or no attention has been paid to the extent to which alterations produced by dissolving substances in it may be the outcome and expression of changes in the water itself. The attempt to extend the 'laws' which are applicable to the gaseous state to liquids has led us away from the truth by narrowing our conceptions. If the contention be justifiable that the alterations attending dissolution are very largely alterations in the character of the water, attention has been directed of late far too exclusively to the dissolved substance.

To give emphasis to this view, I have advocated [1] the restriction of the name *water* to the liquid mixture and have proposed that the simple molecule represented by the symbol OH_2 be termed *Hydrone*. The generalised expression

$$(H_2O)_x \rightleftarrows xOH_2$$

may be considered to be representative of the state of equilibrium in water—that is to say, of the character of the change which water undergoes when the conditions are varied either physically or by dissolving substances in it—in the sense that it pictures the resolution of the more complex into simpler forms and *vice versâ*, without, however, taking into account the variety of molecular forms (x, x^1, x^2 . . . .) which are present.

It is probable that the agreement between 'theory' and practice on which reliance has been placed, particularly in interpreting osmotic phenomena, is more often than not only apparent and fictitious and but the outcome of counterbalancing effects which have been left out of account. We are too prone to believe in constants; we need to remember that, except perhaps in the case of the perfectly gaseous state, *constants are dependent variables.* To take an example, it is assumed that glucose and cane sugar produce like osmotic effects when used in equivalent proportions; indeed, it has been the fashion of late years to treat non-electrolytes as harmless neutrals: in point of fact they differ as much in behaviour as do electrolytes and such a conclusion must be viewed with the gravest suspicion. Recently Dr. Eyre and I have been able to show that three substances so similar as methylic, ethylic, and propylic alcohols produce effects in precipitating salts from solution which are markedly different, propylic alcohol being the most effective although the least soluble. It is clear that the precipitant does not act, in direct competition with the salt, mainly by itself combining with and withdrawing water, but that it promotes the *dissociation of water* by the mechanical interposition of its molecules: in fact, that the 'dehydrating' power *of the water* is enhanced owing to the increase in the proportion of simple molecules in the liquid which is conditioned by the presence of the solute.

The same effect is obvious when the reduction of the electric conductivity of a salt such as potassium chloride by equivalent quantities of the three alcohols is considered. This amounts to about 6 per cent. in the case of methylic, 12 in that of ethylic, and 17 in that of propylic alcohol; the reduction effected by glucose, however, amounts to about 27 and that effected by cane sugar to no less than 42 per cent. In these two latter cases the amount of water actually withdrawn from the solution by the sugar is probably considerable and the 'mechanical effect' of the solute is therefore exercised in a more concentrated solution—more concentrated, that is to say, than those in which the alcohols act. If, therefore, solutions of glucose and cane sugar of equivalent strength produce like osmotic effects, it is because unperceived compensating factors are at work in the solutions which in algebraic sum have the same aggregate influence.

To explain the effect produced by substances which give rise to conducting solutions when dissolved in water (acids, alkalies, and salts), it is necessary to consider the special nature of the changes which may be supposed to attend dissolution in such cases. Why, it may be asked, is an aqueous solution of hydrogen chloride a conductor whilst that of alcohol is a non-conductor? I believe the answer to be that it is because, in the former case alone, the two components of the solution are *reciprocally distributed*; that it is because two correlative systems—

$$HCl\langle^{H}_{OH} \quad \text{and} \quad H_2O\langle^{H}_{Cl}$$

[1] *Roy. Soc. Proc.*, 1908, 31, 80; *Science Progress*, January 1909.

are produced which interact under the influence of the electric stress.[1] In the case of alcohol no such interchange takes place. It may be that the alcohol is hydrolated to some slight extent but the hydrol must be less basic than hydronol; probably, like ammonia, alcohol exists in solution for the most part in the hydronated state:—

$H_2O\begin{matrix}\diagup H \\ \diagdown OH\end{matrix}$	$EtHO\begin{matrix}\diagup H \\ \diagdown OH\end{matrix}$	$EtHO\overline{\underline{\quad}}OH_2$
Hydronol.	Ethanol-hydrol.	Ethanol-hydrone.

Much more must be learnt of the properties of solutions before definite decisions can be arrived at with regard to such delicate and refined issues.

I would apply the interpretation here given of the nature of conducting solutions generally to the explanation of all cases of chemical change: in other words, I assume that in all cases correlative systems are present which are formed by the reciprocal distribution of the interacting substances. From this point of view the solvent is no mere medium but an active participant in the series of interchanges of which, as a rule, only the final product is noticeable.

The solution thus offered of the complex problem discussed very fully in my Address in 1885, which has ever since occupied my thoughts, will, I trust, be found to be helpful, although by no means complete in all its details.

In effect, the doctrine makes no demand which the chemist should not be able to grant forthwith, as it is generally supposed that hydrols are easily formed—to give an example, in the case of the conversion of chloral, $CCl_3.COH$, into chloraldehydrol (chloral-hydrate), $CCl_3.CH(OH)_2$. The novelty of the conception lies in supposing that the occurrence of electrolysis involves the interaction of the hydrol and its correlative and the explanation which it affords of the difference between electrolytes and non-electrolytes.

It is essentially an association theory, although it involves the dissociation of the interacting substances but never the production of separated ions. In the case of aqueous solutions the amount of the distributed substances may be taken as the measure of the activity—of the degree of ionisation, so-called. A wrong view prevails that the so-called molecular conductivities are measures of activity; they are in reality only measures of the relative activities under corresponding conditions of the substances to which they refer. The molecular conductivity of an acid is at a maximum in its weakest solutions: presumably it is then present to the maximum extent in its simplest state and in the active hydrolated state; but as a hydrolytic agent its activity is at a maximum near to the opposite end of the scale. In other words, the hydrolytic activities of a series of acids are in the order of their molecular conductivities in solutions of comparable strength, but molecular-hydrolytic and molecular-electrolytic activity run in opposite directions; the maximum electrolytic conductivity of an acid solution, which is manifest at a particular degree of concentration—presumably at the point at which the two forms of the distributed materials most nearly balance—is also in no way identical with maximum molecular hydrolytic activity. On these assumptions not a few of the deductions based on the ionic dissociation hypothesis are clearly fallacious.

It has been asserted that the association hypothesis does not admit of quantitative treatment, and that therefore it is at a disadvantage; but if the quantitative meaning given to various results in accordance with the

[1] I would repeat the plea I put forward in 1885 that the use of the term hydrochloric acid as applied to hydrogen chloride is undesirable if not unjustifiable; the solution of the gas may be said to contain *chlorhydric acid*, $HCl\ (OH_2)x$. From my point of view, oxygen *is* a constituent of all acids

tenets of the dissociation hypothesis be more often than not one which is inadmissible, little is gained by applying the speculation quantitatively. As already remarked, the only cases in which chemical and electrolytic activity can be compared by the methods proposed are those in which the comparison is made between solutions of comparable or equivalent strength—that is to say, between compounds arranged in vertical series in the order of their activity.[1] Electrolytes are comparable in most, if not in all, their properties when the comparison is made in this way; but order of activity is one thing, actual activity another. It is in this sense and this sense only that we may agree with Arrhenius in his statement, 'L'activité électrolytique se confond avec l'activité chimique.'

The ionic dissociation hypothesis is a beautiful mare's-nest, which fails apparently to fit the facts whenever it is examined. 'And the moral of *that* is,' to quote the words of the classical Duchess so well known to children, we must not use the words *ion* and *ionisation* in any speculative sense but confine their application to cases such as were contemplated by Faraday when he introduced the term ion; the conception of activity, whether electrolytic or chemical, should alone be attached to such words; no idea of actual, separate, individual existence should enter into our minds in using them: the ion is to be thought of merely as the potentially active, transferable radicle in a compound, not as a separated particle enjoying independent existence. It is so easy to speak of dissociation when it is desired to give expression to the idea; the first thing the scientific speaker or writer should guard against is ambiguity.

The subject of gaseous interchanges must not be left out of account, although it is impossible to do justice to it. Mendelejeff's contention that gaseous interchanges are usually bimolecular has been defended by Dixon and Larmor of late. But the facts must be faced. The almost inconceivable frequency of the molecular impacts must not be forgotten. The extraordinary attractive power of the hydrone molecule is also to be remembered: this would tend to promote the formation of aggregates with which the necessary third substance would every now and then form a bimolecular system—which, however, would in reality be at least trimolecular. The proportion of hydrone molecules in a dried gas has probably been under-estimated—the density of hydrone being very low (9)—as no dehydrating agent can be supposed to remove all such molecules or even nearly all; the hydrated substance must have a certain pressure of dissociation. Sir James Dewar's appears to be the only method which is in any way deserving of the epithet absolute; the results he has obtained with helium in a radiometer are strongly in favour of my view. Lastly, the gradual growth in velocity of the explosive wave up to the point of detonation as the compression becomes greater is clear indication that reduction in volume and increase of opportunity for the formation of systems of the proper degree of complexity is a matter of great consequence. Even the behaviour of cordite is significant, particularly the projection of unburnt rodlets of the material from the gun: apparently it is not decomposed by shock intramolecularly but is broken down by heat into gases which interact explosively.

Having dealt with the subjects of chemical change and the nature of

[1] Solutions of acids and alkalies have maximum conducting power at certain relatively high degrees of concentration. Hydrolytic activity also increases steadily in the case of acids as the solution becomes more concentrated; whether it attains to a maximum and whether this coincides with the conductivity maximum is uncertain at present; it is very difficult to decide this point experimentally, as the rate of change is so rapid in strong solution; moreover, the action takes another course in strong solutions, as compounds are formed by the interaction of the hydrolyte and hydrolyst, so that two changes are superposed which cannot well be followed separately.

solutions, however inadequately, I must now endeavour to justify my opening reference to the importance of the organic side of our science.

The province of organic chemistry is so vast that it may appear to be difficult to distinguish the main lines of advance from the by-paths which intersect the field of inquiry in every direction. In reality this is not the case; certain salient features stand out which must attract attention if once attention be drawn to them. The efforts of the chemist to elucidate structure and to correlate structure with function have been extraordinarily successful. In the first place, as already remarked, the student of the subject now has his attention concentrated on the tetrahedron as the symbol of the *functional activity* of carbon; however numerous the compounds, he knows that certain simple rules can be laid down as applicable to all. It is established beyond question that carbon atoms have a remarkable tendency to form ring systems. The affinities of the atom seem to act almost rigidly in certain directions, which appear to be those of lines drawn from the middle point of a regular tetrahedron to its angular points. Rings containing either five or six atoms of carbon are therefore those which are most readily formed and of maximum stability; carbon atoms may and do unite in pairs, threes, and fours, but compounds of this order are far less permanent than those containing either five or six atoms, as the affinities appear to meet in such a manner that they do not satisfy each other and consequently the compounds enter somewhat readily into combination with other substances. When the number of carbon atoms exceeds six, not only is there less tendency to form a ring system but the stability of the system is slight; when the number is considerable, stability is attained by the formation of complex systems consisting of several rings conjoined (camphor, naphthalene, anthracene, etc.).

The behaviour of carbon compounds generally, in so far as this may be regarded as dependent on the condition of the carbon, is extraordinarily simple and may be summed up in the statement that it is either paraffinoid, ethenoid, or benzenoid.[1] Paraffinoid carbon is incapable of combining with other substances and but slightly attractive, so that the hydrogen atoms are by no means easily displaced from paraffinoid compounds;[2] ethenoid carbon combines readily with various substances, forming compounds of paraffinoid type; in the benzenoid state carbon appears to combine somewhat readily with a variety of substances, but the products enjoy only an ephemeral existence and usually escape notice, as they at once break down, giving rise to benzenoid substitution derivatives, so that in this last form carbon simulates the paraffinoid state but is more active.

In earlier years our attention was concentrated on benzene and the benzenoid compounds; much was done to elucidate the structure of these hydrocarbons and of their derivatives; meanwhile these latter have proved to be of extraordinary significance technically, notably as dye-stuffs, but also on account of their medicinal value, as perfumes, and in photography.

The structure of benzene has been the subject of much discussion during the period under consideration. I trust I shall not be accused of parental bias if I urge that the centric[3] formula is the best expression of the

[1] A fourth condition requiring recognition is that of the carbon in acetylene; at present the acetylene compounds are so few in number, however, that this form may be left out of account.

[2] The displacement of the hydrogen associated with carbon is in all probability a secondary phenomenon; it is likely that this is true generally and that hydrogen is never merely removed or attracted away but always has its place taken by a radicle which becomes temporarily attached to the multivalent atom with which the hydrogen is associated.

[3] I have discussed this matter somewhat fully in a recent essay, with reference to the nature of amorphous carbon, in connexion with the remarkable work of Sir James Dewar on the absorption of gases by charcoal at low temperatures (*Journal of the Royal Institution*).

functional activity of the hydrocarbon benzene and its immediate derivatives; the attempts which have been made of late years to resuscitate the Kekulé oscillation hypothesis in one form or another appear to me to be devoid of practical significance. Any formula which represents benzene as an ethenoid must be regarded as contrary to fact. But in considering the properties of benzenoid compounds generally, it is necessary to make use of the Kekulé conception as well as the centric expression. The model of benzene devised by Barlow and Pope subserves a somewhat different and complementary purpose, being primarily of importance on the geometric side in discussing the relation of form to structure.[1]

The discovery of trimethylene by Freund and the subsequent introduction of synthetical methods of preparing polymethylenes by W. H. Perkin, jun., mark the onset of a new era, opening out as they did the possibility of understanding the structure of camphor and the terpenes and other constituents of the volatile oils from plants.

Chemist after chemist had attempted in vain to solve the riddle presented by camphor. Suddenly, in a moment of inspiration, a satisfactory solution of the problem was offered by Bredt. The acceptance of the bridged ring, the special feature of the Bredt formula of camphor, marks the introduction of a new moment into organic chemistry.

The recognition of similar rings in several hydrocarbons of the terpene class, mainly in consequence of the masterly work of von Baeyer, has contributed in no slight degree to an understanding of these compounds; nevertheless, much remains to be learnt and there are many and serious difficulties to be overcome before we shall be in a position to appreciate the genetic relationship of all the substances included in the group. When the account of the work is written it will form one of the most striking and fascinating chapters in the history of our science.

Among the many names of those who have contributed to its development the first to be mentioned is that of Wallach, to whose unwearied efforts,

[1] The time is now approaching when it will be possible to extend the study of benzenoid compounds beyond the formal and superficial stage; hitherto we have been content to develop the methods of preparing such substances and to determine their number and their distinctive properties. Everything has to be learnt as to the exact character of the changes which attend their formation from the parent substance benzene and as to the exact nature of their inter-relationship. The impression produced by benzene, in my mind, is that of an eminently plastic system capable of responding to every slight change that may be impressed upon it. Nothing is more remarkable than the difference between benzene and its homologues, so obvious in the extraordinary increase in activity which attends the introduction of hydrocarbon radicles in place of one or more hydrogen atoms. But such plasticity is not characteristic of benzene only: if the properties of benzenesulphonic acid be contrasted with those of the various substituted sulphonic acids, it is clear that every variation in the nucleus meets with some response from the sulphonic group; what is still more remarkable, if the hydrogen in the hydroxylic group in the phenolsulphonic acids be displaced by other radicles, not only does the oxygen atom to which the radicle is attached seem to respond to the change but the benzenoid system and the still more distant sulphonic system are also both affected. It is well known that the physical constants are all variables in the case of benzenoid compounds. Perhaps the most remarkable confirmation of the view here advanced, however, is that afforded by the conclusion arrived at by Barlow and Pope that in the case of benzene derivatives, although the spheres of influence of the carbon and hydrogen atoms are relatively the same as in the parent compound, the spatial arrangement of the component spheres of atomic influence remaining practically unchanged, nevertheless the actual volumes of the spheres of influence of both carbon and hydrogen alter proportionally to the alteration in molecular volume. Thus they maintain that in the case of the conversion of benzene (molecular volume 77·4) into tetrabromobenzene (molecular volume 130·2), the volumes of the spheres of influence of both carbon and hydrogen expand in the ratio of 77·4 : 130·2. Such a conclusion is very noteworthy,

continued during a long series of years, so much is owing. The synthetic work carried out with brilliant success in recent years by W. H. Perkin may also be referred to as of extraordinary promise but of wellnigh inconceivable difficulty.

Before leaving this chapter reference should be made to the almost protean character of camphor, as disclosed by the work of inquirers such as Kipping, Pope, Forster, Lapworth, and Lowry; no other substance has lent itself to use in quite so many directions and with such fruitful results. Special mention may be made of the demonstration which Pope has given, with the aid of the camphor-sulphonic acids, that nitrogen, sulphur, selenium, and tin give rise to optically active substances in all respects analogous to those furnished by carbon. The success with which Kipping's arduous labours have been crowned is also very noteworthy, taking into account the many difficulties he has overcome in preparing optically active silicon compounds. The extension of the Pasteur-van't Hoff theory of asymmetry inferentially to all elements which are at least quadrivalent, now accomplished, is of superlative importance.

Lowry's refined observations on the conditions which determine the interconversion of isodynamic forms of some of the camphor derivatives may also be cited as of special value as a contribution to the study of metamerism and the conditions which determine chemical change generally.

Not the least interesting feature of camphor is the light thrown by its behaviour on the influence which oxygen exercises as an attractive element and on the part which spatial configuration may play in determining directions of change. It is clear that, whatever the agent, the attack is always delivered from the oxygen centre and that the direction in which the attack becomes effective depends on the position which the agent can take up relatively to the various sections of the molecule.[1]

It must be confessed that our efforts to penetrate behind the veil in the case of the higher carbohydrates—starch and cellulose in particular—have not been rewarded with success.

Moreover, though much has been done of late years to unravel the nature of the vegeto-alkaloids, substances such as quinine are still only partially deciphered and not one of the more complex alkaloids has been produced synthetically. In view of the fact that quinine is still the one effective and practically safe anti-malarial medicine, the disclosure of its constitution is much to be desired. The isolation of adrenaline from the suprarenal capsule and the discovery that this alkaloid—which is an extraordinarily active substance physiologically—plays a most important part in controlling vital processes is of supreme interest. Other glands—the pituitary gland, for example—appear to contain peculiar active substances which are of particular consequence in regulating animal functions. The discovery of such substances affords clear proof that life is largely dependent on what may be termed chemical control.

In addition to indigo, the simpler yellow and red natural colouring-matters have now been thoroughly examined but this class of substance still affords abundant opportunity to investigators. Kostanecki's comprehensive studies of the xanthone group may be referred to as of particular value.

Attention may be directed here to the investigation of brazilin and haematoxylin by W. H. Perkin and his various co-workers, not merely as being full of interest and importance as a contribution to our knowledge of the relation between colour and structure and as a brilliant example of technical skill, but because of the illustration it affords of the extreme intricacy of such inquiries and of the vast amount of labour they entail. The general public probably has not the slightest conception of the difficulties which attend such research work and of its costliness.

[1] Cf. *Chem. Soc. Trans.*, 1902, 81, 1469.

As an investigator of vegetable colouring-matters, no one has been more assiduous or has displayed greater skill of late years than A. G. Perkin. His recent refined investigation of the colour-yielding constituents of the indigo plant is of exceptional value at the present time, although it is to be feared that it comes too late to save the situation in India. The work of the brothers Perkin, it may be pointed out, is of exceptional interest on the human side as well as from the scientific standpoint, as their enthusiasm and wonderful manipulative skill afford a striking and noteworthy example of hereditary genius.

Two substances of commanding interest which have long resisted attack —the red colouring-matter of the blood and leaf-green—are at last going the way of all things chemical, as the secret of their nature is being wrung from them. In Willstätter's skilful hands chlorophyll is proving to be by no means the fugitive material it was supposed to be; the complexity of the problem it offers, however, seems to be far beyond anything that could have been anticipated; so much greater will be the interest attaching to the final solution. The discovery that green chlorophyll is a magnesium salt is of special importance, as the first clear indication of the manner in which magnesium salts are of service to plants.

Apart from the special interest which attaches to the investigation of vegetable colouring-matters on account of their being coloured substances, such inquiries are of value as furnishing material for the discussion of the metabolic activity of plants.[1]

Even colloids are being brought into line. Studded as they are with active centres (oxygen or nitrogen atoms), they seem to be able to attract and retain hydrone molecules at their surfaces in ways which give them their peculiar glue-like attributes: as a consequence living tissue appears to be little short of animated water.

To the present generation of students, the organo-metallic compounds must have appeared to belong to the past; the discovery of methides of platinum and gold by Pope will not only serve to reawaken interest in this group of compounds, but is of primary importance as a contribution to our knowledge of the valency of these elements; the stability of the platinum derivatives is altogether astonishing.

The discovery announced in June last, at the International Congress of Chemistry, by Mond of compounds of carbonic oxide with ruthenium and uranium is a striking and most welcome extension of his previous labours, which had placed us in possession of carbonyls of nickel, iron, and cobalt.

[1] But a note of sadness pervades the story. The effect of learning to understand Nature always appears to be that we at once brush her aside when we have wrested from her the secrets which she has so long preserved inviolate. No sooner did we learn the nature of the madder colouring-matters than we proceeded to prepare them artificially—thus putting an end to the cultivation of a valuable crop. Indigo is meeting with a like fate, a catastrophe which might well have been avoided had scientific assistance been called in at the proper time. Not content with making natural colouring-matters, we set to work to outrival the rainbow in our laboratories; the feminine world is decked with every variety of colour in consequence, although unfortunately our blends too often lack the beauty of those of truly natural origin, which rarely, if ever, offend the eye. We congratulate ourselves on our cleverness in thus imitating Nature but no idea of thrift possesses us: moreover, our attempts to imitate if not to undo her work are never direct but are always made with her aid, with Nature's product—coal; we are no longer content to ride on horseback but must rush through space, and instead of watching the birds fly seek to emulate them but always with the aid of fuel won by Nature from the soil and air in days long past. Too much is being done in every direction to waste natural resources, too little to conserve them, too little to employ man in his proper place—as tiller of the soil. Here lies the chemist's opportunity. At no very distant date, perhaps, when petrol is exhausted, toll will be taken from the sun in the form of starch or sugar and this will be converted into alcohol.

The metallic carbonyls possess altogether remarkable properties: at present, these defy explanation; nickel carbonyl in particular seems to be an exception to all rules. The complex iron carbonyls made known by Dewar and Jones also have most fascinating attributes, the variety of colours they display being specially interesting. The marked individuality of the members of the iron group exemplified in their carbonyl derivatives is in striking contrast with the tendency they display to behave as related elements; the deeper problems of valency are clearly exposed for consideration in such peculiarities.

The discoveries of the special activity of magnesium as a synthetic agent and of the superior value of nickel as a catalyst in fixing hydrogen are other illustrations of the individuality of metallic elements. We are greatly indebted to the French chemists for the invaluable preparative methods they have based on the use of these two agents.

Although satisfactory progress has been made in almost every direction, the nature of many nitrogen compounds is still not properly understood. It is clear that we are as yet in no way seized with understanding of the attributes of this element as we are of those of oxygen and carbon, particularly in the case of mixed carbon-nitrogen compounds: we can make nothing of the physical data such substances afford. Nitrogen, in fact, is an extraordinary element, far more remarkable than any other; its 'temper' appears to vary more than that of any other element according to the character of its associates—nothing could be more remarkable, for example, than the change in properties from ammonia, NH_3, through hydrazine, $NH_2.NH_2$, to azoimide, N_3H. No other element can be so poisonous, so immediately fatal to life. We lack a model symbolic of its functions—which means that we are unable to fathom its vagaries and reduce them to simple order.

The oximes and the diazo-compounds in particular have given rise to much dispute. Stereo-chemical formulæ have been assigned to these, but probably they have little relation with the truth; although they have been of service by supplying symbols which can be offered up at examinations, by confining attention they have served to sterilise inquiry. No better illustration could be given of the truth of the remark made by my friend the Professor that man is an idolater by nature, a fact that chemists should always bear in mind.

The compounds in question are difficult substances to handle, far too prone to undergo change without invitation—it is to be feared that many of the conclusions which have been arrived at are based on incomplete if not unsatisfactory evidence.[1] When I think of the state of our knowledge, I am reminded of the father of diazo-chemistry, Peter Griess, a man of marvellous experimental gifts; there is great need of such a man to reinvestigate the whole subject.

If we inquire as to the general effect of the increase of knowledge of organic compounds, it is clear that the lessons which emerge from all modern inquiries are such as to justify Larmor's remark that our conceptions of structure must be granted more than analogical significance. Everything tends to show that function and structure are most closely connected—odour, taste, colour, physiological effect are specific rather than general properties, each conditioned in its special variety by some special structure; we are

[1] Since this was written, Thiele's discovery of 'Azomethane,' MeN : NMe, has been announced. This is described as being a distinctly coloured, very pale yellow substance in the solid state. There can be little if any doubt, therefore, that, as Robertson and I have argued, the colourless so-called syn- and anti-diazo-salts cannot possibly be compounds of the —N : N— or diazene type: such compounds would all be at least yellow in colour.

approaching very closely to a time when it should be possible to discuss such properties with considerable confidence.

Still it must not be forgotten that the problems they offer are all valency problems and that the nature of valency eludes us entirely at present.

The greatest advance which chemists may pride themselves upon having made during the past decade or two remains to be considered. In 1885, I spoke as follows:—'The attention paid to the study of carbon compounds may be more than justified both by reference to the results obtained and to the nature of the work before us; the inorganic kingdom refuses any longer to yield up her secrets—new elements—except after severe compulsion; the organic kingdom, both animal and vegetable, stands ever ready before us. Little wonder, then, if problems directly bearing upon life prove the more attractive to the living. The physiologist complains that probably 95 per cent. of the solid matters of living structures are pure unknowns to us and that the fundamental chemical changes which occur during life are entirely enshrouded in mystery. It is in order that this may no longer be the case that the study of carbon compounds is being so vigorously prosecuted. Our weapons—the knowledge of synthetical processes and of chemical function—are now rapidly being sharpened, but we are yet far from ready for the attack.'

My forecast has been more than justified; indeed, the advance to be recorded is nothing short of marvellous: the great problems of vital chemistry appear now no longer to be unattainable to our intelligence—their cryptic character seems to have disappeared almost suddenly. Many have contributed in greater or less degree but none in such measure as Emil Fischer, whose work both in the sugar group and in connexion with the albuminoids must for ever rank as monumental.

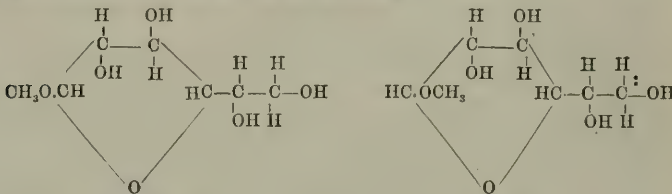
It is difficult to appreciate the extent to which the practical genius of this chemist has carried us—difficult alike for those who understand the subject and those who do not; the significance of his labours is only apparent when the bearing of his results on the interpretation of vital phenomena is fully considered. In 1885, we were disputing as to the structure of substances such as glucose and galactose; now we not only are satisfied that they belong to the group of aldhexoses (aldoses) derived from normal hexane but, taking into account the monumental discoveries of Pasteur to which precision has been given by van't Hoff's great generalisation, we are in a position to assign fully resolved structural formulæ not only to the natural products but to the nine other isomeric aldhexoses which Fischer has prepared artificially.

It is a striking fact that only three of the sixteen possible aldhexoses and but a single ketohexose (fructose), of which many are possible, are met with naturally. Nature is clearly most sparing, most economical, in her use of materials. And not only is this true of the hexoses, as very few of the possible lower and higher homologous carbohydrates occur in vegetable or animal materials and the condensed carbohydrates (cane sugar, starch, etc.) are all formed apparently from the hexoses and pentoses which occur naturally. The albuminoids, the alkaloids, the terpenes are also optically active substances; in other words, only a limited number of the possible forms are present. There is reason to suppose that the compounds of natural occurrence stand in close genetic connexion and belong with few exceptions to the same series of enantiomorphs; in no other way is it possible to account for the occurrence of one only of the pair of enantiomorphous isomerides and for the relatively small number of compounds. Moreover, not only the sugars and most of the other products of the disintegration of the albuminoids but also the amino-acids, in like manner, are derivatives of compounds containing at most six atoms of carbon; the fats alone are of a considerably higher degree of complexity but they are probably collocations of the simpler units.

The terpenes and essential oils are mostly C_{10} derivatives; the alkaloids have complex formulæ but the units of which they are composed are simple; as all of them are optically active, it is clear that only some of the possible enantiomorphous combinations are present.

We are bound, therefore, to assume that a large proportion of the changes which occur in living organisms—which constitute vital metabolism—are directed changes. What is the nature of the directive power? We are already able to go far in explaining this, although our knowledge is mainly of analytical changes, the nature of synthetic changes being, at present, only inferentially disclosed to us.

It has long been known that under natural conditions many complex compounds such as starch, cane sugar and other similar substances are broken down hydrolytically, not by the unassisted action of water but by the co-operation of enzymes; the effect produced by these enzymes is precisely similar to that of acids, except that all acids produce the effect, acting only with different degrees of readiness, whilst enzymes are strictly selective, a given enzyme acting only, as a rule, either on a single substance or on a series of substances similar in structure. Indisputable evidence has been obtained that the enzymes which act on the carbohydrates are intimately related in structure to the compounds which they attack, fitting them—to use the apt simile introduced by E. Fischer—much as a key fits into a good lock: the slightest alteration in the structure of the carbohydrate is sufficient to throw the enzyme out of action. The closeness of the association is well illustrated by the case of the two methylglucosides, which differ merely in the manner displayed by the following formulæ:—



α-Methylglucoside. β-Methylglucoside.

The relative positions of the simple hydrogen atom and of the hydroxyl group attached to the carbon atom are merely interchanged, yet this is sufficient to render the one (the α) proof against the action of emulsin—the enzyme of the almond—the other (the β) proof against that of maltase—the enzyme present in yeast.

The enzyme may be pictured as attaching itself to a surface of the molecule and at the same time as associated with hydrone in such a manner that this is brought to bear at the junction which undergoes disruption. The action of acids, although similar, is simpler in that the attachment is not to the molecule as a whole but only at or near to the junction which is resolved.

In the case of the albuminoids, the action is probably more local in character, in so far as the resolution of their polypeptide section is concerned, the same enzyme being able to effect the resolution of a considerable number of compounds.

All the peptolytes have in common the junction C.CO.N; the peptoclasts by which such substances are gradually resolved probably fit this group alone; other enzymes are of more complex organisation, akin to that of the sucroclasts—such as arginase, for example. In principle, however, the enzymes are to be regarded as all acting alike, each as fitting some particular asymmetric centre if not the whole of the molecule which undergoes

hydrolytic disruption under its influence, the asymmetric centre being that at which the cleavage is effected.

In synthetic changes the operation is reversed. It may be supposed that the separation of hydrone is determined by the circumstance that water can be formed by the interaction of this hydrone as it separates with that which is attached to the hydrolated enzyme; the formation of water from hydrone, in fact, plays a great part in such changes.

The action of oxydases may be regarded from a similar point of view. The early observations of Adrian Brown on the oxidising activity of *Bacterium Xylinum*, coupled with the later work of Bertrand, affords clear proof that these enzymes are possessed of selective powers. It is conceivable that such enzymes become attached to a molecule at some one centre and that they then deliver their attack at some more or less distant point by presenting the oxygen with which they are loosely associated at this point. It is easy, on such an assumption, to understand how ethenoid linkages may be developed in various positions in the molecule of a fatty acid.

Rosenthaler's recent observations on the formation of optically active phenylhydroxycyanomethane, PhCH(OH)CN, from hydrogen cyanide and benzaldehyde on shaking the solution with emulsin are, however, among the most significant yet made. I have myself confirmed his statements. The ease with which the change takes place—the manner in which the change is accelerated by the enzyme—is altogether remarkable.

Although there can be little doubt, in the case of plants and animals, that the synthetic processes do not occur spontaneously and directly between the interagents but are for the most part at some stage or other directed or controlled, it cannot well be supposed that every asymmetric compound is the direct outcome of a controlled process; nor is it necessary to assume that such is the case. Not a few asymmetric compounds are probably but secondary products formed by the breakdown of compounds which are the products of directed synthesis.

Ehrlich's observations on the formation of the amylalcohols from the isomeric aminocaproic acids (leucines) may be referred to in this connexion. Taking into account the manner in which the vegetable organism is provided with conservative powers and its tendency to retain nitrogen, in view of the peculiar structure of the members of the terpene group—especially the presence of the isopropyl group and of methyl in association with the ring in such hydrocarbons—it is highly probable that the terpenes are derived from amino-acids. A molecule of leucine, a molecule of alanine, and a molecule of formaldehyde obviously provide the materials for the production of methylisopropyldihydrobenzene; it is not difficult to picture the series of changes which would lead to the formation of the hydrocarbon from such a conjunction.

The general impression produced by facts such as have been referred to is that directive influences are the paramount influences at work in building up living tissues. These come into operation, it is to be supposed, at a very early stage in the case of the plant. The initial step probably involves the electrolysis of water under the influence of solar energy and the reduction by the hydrogen thus liberated of the carbon dioxide, which is eventually converted into formaldehyde, either directly or, it may be, through the intermediation of oxalic and formic acids. The part which chlorophyll plays in this process can only be surmised: it is not improbable that reduced chlorophyll is the active reducing-agent: that chlorophyll itself is active in conditioning the resolution of water under the influence of solar energy into reduced chlorophyll and oxygen or, more probably, a labile peroxide, from which oxygen is independently split off at a subsequent stage, it may be under the influence of a so-called catalase.

Whatever the process by which the plant acquires its initial store of carbonaceous material, the formaldehyde is apparently at once made use of

and in part at least converted into starch. The view may be taken that glucose is the primary product of condensation—that the formaldehydrol molecules become ranged against a glucose template in series of sixes, which are soldered by enzymic influence into a single molecule by the interaction of contiguous hydrogen and hydroxyl radicles along the chain.

The glucose is thereafter carried a stage higher and converted into maltose or it may be that a maltose template is effective from the beginning and that the biose is the immediate product of condensation; the conversion of maltose into starch must take place in some similar manner. The recent observation that cellobiose is a β-glucoside enables us to realise that the formation of cellulose differs from that of starch in that the glucose molecule, instead of being converted into the β-glucoside maltose, becomes changed into the correlated β-glucoside, a membrane being thus secured which can resist the diastic enzymes by which starch is attacked.

The formation of the albuminoid substances may be regarded from a similar point of view. At present, however, there is no satisfactory evidence to show at what stage nitrogen is introduced into the molecule. As the plant takes up nitrogen in the form of nitrate, not as ammonia, it is probable that the nitrate is reduced to hydroxylamine and that this rather than ammonia is the active synthetic agent. Formaldehyde and hydroxylamine would yield formaldoxime, which would easily pass into methylamine on reduction; the interaction of formaldoxime and formaldehydrol might give rise to a higher aldoxime which would be easily convertible into amino-acetic acid (glycine). Higher glycines might be formed from glycine by syntheses similar to those Erlenmeyer has effected; but to account for the formation of asymmetric amino-acids it is necessary to assume that the action is controlled at this stage and that the glycine is formed against a template perhaps under the influence of an enzyme.

Another conceivable mode of formation is by the fermentative degradation of glucosamine.

Until we know more of the order in which the amino-acid radicles are united in the various albuminoids and of the character of the associations other than those which are characteristic of polyeptides, we can consider the formation of albuminoids only from a very general point of view; but taking into account the very different proportions in which amino-acids and other cleavage products are formed on hydrolysing substances of different origin, it is clear that the several sections of the molecule must be differently ordered in the different proteins; again, therefore, it is necessary to assume that the formation of such substances is directed. We may picture molecule after molecule as being ‘brought into line’ against a template and the junctions which are required to bind the whole series together as being made through the agency of the enzymic dehydrating influence before referred to.

Attention has been called to the relatively simple way in which the hydrocarbons are constructed, that even the paraffins are not to be visualised as so many ducks strung upon a ramrod, Münchausen fashion, but as forming curls, owing to the natural set of the affinities. This probably is true of complex substances such as the proteins.

Protoplasm, in fact, may be pictured as made up of large numbers of curls, like a judge's wig—all in intercommunication through some centre, connected here and there perhaps also by lateral bonds of union. If such a point of view be accepted, it is possible to account for the occurrence in some sections of the complex series of interchanges which involve work being done upon the substances brought into interaction, the necessary energy being drawn from some other part of the complex where the interchanges involve a liberation of energy.

The conclusions thus arrived at may be utilised in discussing the problem of heredity. The inheritance of parental qualities, the need to assume

continuity of the germ plasm and the comparative unimportance from the standpoint of heredity of somatic qualities, as well as the non-inheritance of mere environmental effects (acquired characters), are all necessary consequences of the view I have advanced.

The general similarity of structure throughout organised creation may well be conditional primarily by properties inherent in the materials of which all living things are composed—of carbon, of oxygen, of nitrogen, of hydrogen, of phosphorus, of sulphur. At some early period, however, the possibilities became limited and directed processes became the order of the day. From that time onward the chemistry prevailing in organic nature became a far simpler chemistry than that of the laboratory: the possibilities were diminished, the certainties of a definite line of action were increased. How this came about it is impossible to say; mere accident may have led to it. Thus we may assume that some relatively simple asymmetric substance was produced by the fortuitous occurrence of a change under conditions such as obtain in our laboratories and that consequently the enantiomorphous isomeric forms of equal opposite activity were produced in equal amounts. We may suppose that a pool containing such material having been dried up dust of molecular fineness was dispersed; such dust falling into other similar pools near the crystallisation point may well have conditioned the separation of only one of the two isomeric forms present in the liquid. A separation having been once effected in this manner, assuming the substance to be one which could influence its own formation, one form rather than the other might have been produced. An active substance thus generated and selected out might then become the origin of a series of asymmetric syntheses. How the complicated series of changes which constitute life may have arisen we cannot even guess at present; but when we contemplate the inherent simplicity of chemical change and bear in mind that life seems but to depend on the simultaneous occurrence of a series of changes of a somewhat diverse order, it does not appear to be beyond the bounds of possibility to arrive at a broad understanding of the method of life. Nor are we likely to be misled into thinking that we can so arrange the conditions as to control and reproduce it; the series of lucky accidents which seem to be required for arrangements of such complexity to be entered upon is so infinitely great.

The ovum and the spermatazoon must be supposed to have all the directive influences stored up in them which are subsequently brought into play in the development of the organism; they may be looked upon as bundles of templates of very definite structure. As both paternal and maternal qualities may be handed on to the offspring, and as there is so near an equality of the sexes in the higher organisms, it appears likely that the male and female elements are produced in equal numbers by both parents, either the one or the other becoming developed at conception, according to the accidents of the moment, whereby both the sex of the offspring is determined and whether it be primarily derived from the one or the other parent.

There cannot well be complete interpenetration of the two elements: rather is it to be supposed that surface contacts are established which lead to transferences from one to the other chromasome; to use vulgar terms, that eyebrows are pencilled, the nose straightened, narrowed or broadened, hair made fair or dark; that by interpenetration of the curls this or that other quality is modified by a molecule being plastered on here, another smoothed off there, while cross-connexions are established in some directions but broken in others.

Such a picture cannot be regarded as extravagant. We may even claim literary appreciation in support of our temerity—no less a writer than Emerson, for example, as witness the following passage in his 'Uses of Great Men':—

'Light and darkness, heat and cold, hunger and food, sweet and sour, solid, liquid and gas circle us round in a wreath of pleasures and, by their agreeable quarrel, beguile the day of life. The eye repeats every day the first eulogy on things: "He saw that they were good." We know where to find them; and these performances are relished all the more after a little experience of the pretending races. We are entitled also to higher advantages. Something is wanting to science until it has been humanised. The table of logarithms is one thing and its vital play in botany, music, optics, and architecture another. There are advancements to numbers, anatomy, architecture, asstronomy little suspected at first, when, by union with intellect and will, they ascend into the life and reappear in conversation, character, and politics.

'But this comes later. We speak now only of our acquaintance with them in their own sphere and the way in which they seem to fascinate and draw to them some genius who occupies himself with one thing all his life long. The possibility of interpretation lies in the identity of the observer with the observed. Each material thing has its celestial side; has its translation, through humanity, into the spiritual and necessary sphere, where it plays a part as indestructible as any other. And to these their ends all things continually ascend. The gases gather to the solid firmament; the chemic lump arrives at the plant and grows; arrives at the quadruped and walks; arrives at the man and thinks. But also the constituency determines the vote of the representative. He is not only representative but participant. Like can only be known by like. The reason why he knows about them is that he is of them; he has just come out of nature or from being a part of that thing. Animated chlorine knows of chlorine and incarnate zinc of zinc. Their quality makes his career and he can variously publish their virtues because they compose him. Man made of the dust of the world does not forget his origin; and all that is yet inanimate will one day speak and reason. Unpublished nature will have its whole secret told.'

Our modern faith in the ultimate power of scientific inquiry to appreciate their precise character, if not to solve the most difficult of problems, is clearly leading us to seek in incarnate oxygen, in incarnate hydrogen, nitrogen, and a few other elements the secrets even of life itself.

We are undoubtedly what we are in virtue of the fact that carbon and hydrogen and oxygen and nitrogen are possessed of certain qualities—of qualities which permit them to take part in the formation of plastic and multimutable structures. No other elements apparently could lend themselves to the purpose; they would only furnish rigid structures; so that if there be life upon other worlds than ours it is probably not so very different from that with which we are acquainted.[1] The uniformity of plan upon which the world of life is constructed is indeed remarkable. Obviously if the control were not a very rigid one, if possibilities of change were not strictly limited, the world would be full of abortions.

[1] It has been suggested by Lord Kelvin and others that life may have been conveyed to our earth by meteorites. The experiments made, with Sir James Dewar's assistance, by Dr. Macfadyen prove that micro-organisms are not killed, even when cooled to the temperature of liquid hydrogen, so that they might resist the cold of space. Arrhenius has suggested in his 'Worlds in the Making' that organisms may be conveyed directly from planet to planet by the agency of radiation pressure. Such organisms would be subjected, however, not only to intense cold but also to the action of ultra-violet light. Sir James Dewar was good enough recently to allow me to witness experiments he has been making to ascertain the effect of subjecting organisms which survive exposure in liquid air to the radiation from a quartz-mercury-glow-lamp while cooled in liquid air. He finds that, under such conditions, the organisms no longer survive. It would seem, therefore, that we must be content to consider the origin of life in our own planet and not throw the responsibility back on one of greater age.

The manner in which development proceeds must depend (1) on the fundamental properties of the constituent primary units—that is to say, the elementary atoms; (2) on the structure of the germinal masses; (3) on the available primary food materials; and (4) on the character of the operative enzymes, whose work it is to incorporate into the protoplasmic complexes the scattered elements as they come into position on the various templates the nuclei afford.

It would seem that control is exercised and stability secured in several ways; not only is the form laid down in advance, but certain chosen materials are alone available and the builders can only unite particular materials in particular ways. Growth must depend on the presence of the necessary materials in great variety and in proper proportions. From this point of view the minor constituents of food are equally as important as the major constituents; the value of a varied as well as of a sufficient diet cannot be overestimated, in fact. Yet it is probable that there is a certain degree of equivalence and that within limits one simple material may take the place of another; in any case, that growth may be favoured in this or that direction by the relative preponderance of a particular food material.[1] It is conceivable that variation may arise by the accidental intrusion of a new structural unit into the complex; it is more probable perhaps that it is usually a consequence of growth in directions which, although possible, had not been favoured previously by the conditions.

But if such argument be sound, what are its consequences? Miss Barrington and Professor Karl Pearson conclude a recent communication from the Francis Galton Laboratory for National Eugenics with the words: 'The first thing is good stock and the second thing is good stock and the third thing is good stock, and when you have paid attention to these three things, fit environment will keep your material in good condition. No environment or educational grindstone is of service unless the tool to be ground is of genuine steel, of tough race and tempered stock.'

I will venture to assert that our chemical experience, especially our knowledge of enzymes, is in complete harmony with this conclusion.

Questions such as these are the questions of the future and they are the questions that should be discussed by us at our meetings on account of their public importance. To repeat Emerson's words—something is wanting to science until it is humanised. The present is controlled by the past and the present will control the future; the part played by education must be altogether subordinate: the provision of the right material to be educated must be the main consideration. Nothing could be worse than our present system; we place no hindrance in the way of the unfit, and those who are presumably the fittest are failing to contribute in proper proportion to the perpetuation of their race. The condition of affairs to-day affords a most striking exemplification of the slowness with which civilised nations are learning to appreciate the lessons of science.

Recently I attended the celebration at Cambridge of the fiftieth anniversary of the publication of Darwin's revolutionary work, 'The Origin of Species,' in which the famous doctrine of Evolution was developed. Men of distinction from all parts of the world were there but not one word was said of the tremendous import to humanity of the message which Darwin delivered. What is even more startling, at Cambridge and, of course, equally at Oxford, it is in no way required of students either at entry or during their period of residence that they shall be sufficiently acquainted with Darwin's work to grasp its significance and its consequences;

[1] It is from this point of view, and not on the ground of any measure of temporary success, that the advocates both of a spare diet and of vegetable food alone must be judged; in all such cases we have to consider the influence on the race, not merely the immediate effects.

practically only the few who study biology become aware of it.[1] And yet we never tire of preaching the value of classical learning and of history. The real history that counts and that training in scientific method which would tend to broaden and inform the mind are in no way thought of by the literary triflers who pretend to guide the destinies of our youth. Surely some effective means must be devised that will enable us to revolt without further delay against our unnatural and generally worthless system of school and university training.

No problem can compare in importance with that of the future of our race. To consider it is the one plain duty before us and the need becomes daily a more urgent one. Not only do we encourage deterioration at the lower end of the scale of intelligence in the manner pointed out in the passage quoted from Darwin, we are now through our system of higher education courting failure also at the upper end. Herbert Spencer forcibly drew attention many years ago to the tendency which the development of individuality must have to depress fertility and to the evil effects of severe mental labour on women especially. It has been stated that in the United States of America the higher education of girls has been proved to sterilise them. Many of us probably have experience within our own circle of observation which would justify such a conclusion; there are so many ways in which education operates to retard marriage, even if it have no direct effect on the organism.

Even if man-stuff and woman-stuff be in no fundamental way different materials, there are essential differences between the sexes which must be taken into consideration. During the active period of her life the woman is subject at intervals to influences which do not affect the man; various excitants (so-called hormones) come into operation and produce effects which are altogether remarkable; her mental condition is consequently in a state of continued flux. Cause and effect in these cases are undoubtedly chemical in their nature. The changes which attend puberty are probably brought about by the more or less sudden outpouring of peculiar secretions which direct metabolism into new and special channels. It is clear that mental states have an important influence on metabolism, and that if influences are brought to bear from which the organism has been exempt in the past, effects must be produced the nature of which it is impossible to predict; therefore the creation of new interests may well be a source of most serious danger. The most disquieting feature of the times is the revolt of women against their womanhood and their claim to be on an equality with man and to compete with men in every way. There should be no question of equality raised; when comparison is made between complementary factors the question of equality does not and cannot come into consideration. It is clear that should the struggle arise—and it is to be feared that it is coming upon us—there can be but one issue: woman must

[1] Warning is given by Darwin in simple but explicit terms in the following passage in his *Descent of Man*:—'With savages, the weak in body or mind are soon eliminated; and those that survive commonly exhibit a vigorous state of health. We civilised men, on the other hand, do our utmost to check the process of elimination; we build asylums for the imbecile, the maimed and the sick; we institute poor-laws; and our medical men exert the utmost skill to save the life of everyone to the last moment. There is reason to believe that vaccination has preserved thousands who from a weak constitution would formerly have succumbed to small-pox. Thus the weak members of civilised societies propagate their kind. No one who has attended to the breeding of domestic animals will doubt that this must be highly injurious to the race of man. It is surprising how soon a want of care or care wrongly directed leads to the degeneration of a domestic race; but excepting in the case of man himself, hardly anyone is so ignorant as to allow his worst animals to breed.'

fail, and in failing must carry man with her to destruction, for she will inevitably cease to exercise her specific womanly functions with effect, so delicate is the adjustment of her mechanism. The evolution of the two sexes has been on different lines and different qualities have been developed in them; it is probable that the germinal differences are profound. And education cannot remove the difference; although education may condition functional disturbances, it must be powerless to modify the structure and mechanism. Man is in no way what he is to-day in virtue of the education he has received during a few generations past; the education of the race throughout time has been something entirely different from what is thought of now as education. 'Nature, the dear old nurse,' not man, has done the work by a severe and drastic process of selection—by picking out men capable of doing men's work and by picking out women capable of doing women's work: she has constituted them helpmates and has had no thought of their being so silly as to wish to get in one another's way; this is a state brought on by an artificial, unsuitable system of education.

The subject has been brought before the chemical world in England recently by the application of a number of women to be made Fellows of the Chemical Society. Many of us have resisted the application because we were unwilling to give any encouragement to the movement which is inevitably leading women to neglect their womanhood, which is in itself proof that they do not understand the relative capacities of the two sexes and the need there is of sharing the duties of life. If there be any truth in the doctrine of hereditary genius, the very women who have shown ability as chemists should be withdrawn from the temptation to become absorbed in the work, for fear of sacrificing their womanhood; they are those who should be regarded as chosen people, as destined to be the mothers of future chemists of ability. The argument is applicable generally; it is surely desirable in all cases of declared ability that the education of girls should be directed so as to produce not merely minimum disturbance of the woman's attributes and charms but full understanding of the unique position of responsibility she occupies in the scheme of life.

Questions such as I have raised are of the utmost importance as bearing on educational policy. Our ideas of education are in almost as inchoate a state as they were in 1885. We have been led, it is true, to recognise that our scheme of popular elementary education is a terrible failure, that its whole tendency has been to emasculate our population; yet at the very time that we are making this discovery we are beginning to force our higher education along lines which experience shows must be ineffective—along literary lines. I should be the last to deny that there is an undercurrent of improvement perceptible, but this is directed only by sporadic influences and is in no way favoured by most of those in authority. We are still suffering at the hands of those who have been our persecutors in the past—the clerics, who control most of the schools and whose outlook is almost as narrow as it ever was. The saving grace of science has in no way entered into their souls—how can it? The Universities make no attempt to secure their redemption. London of late years has even reversed the enlightened policy the University so long pursued and has allowed Latin to figure as alternative to science, not as the complement of science.

Our Association seems to have little or no effect on the public conscience. And the explanation is not far to seek. Our interests are too special; we are all too much wrapped up in our own affairs; too inconsiderate to co-operate effectively. We forget or do not realise that 'Something is wanting in science until it has been humanised'; we make no attempt to organise our forces and make good the claim we put forward to be the possessors of superior knowledge. A complete change of attitude on our part is required; we need to play the part of propagandists. We are almost unknown as

popular writers and the days of popular lectures are past. Practically nothing is done to train the public mind and school science is in no way effective.

To speak particularly of my own subject, it is impossible to rate chemistry at too high a value in Canada. The maintenance of the fertility of your fields, the proper utilisation of your vast mineral wealth, the purity of your food supplies [1] will depend mainly on the watchful care and skill of chemists; but the educational value of the subject may also be set very high. If properly taught in your schools, it will afford a means superior to all others, I believe, of training faculties which in these days should be developed in every responsible citizen. No other subject lends itself so effectively as a means of developing the experimental attitude of mind—the attitude of working with a clearly conceived purpose to a desired end, which is so necessary to success in these days; and if care be taken to inculcate habits of neatness and precision and of absolute truthfulness, if care be taken to teach what constitutes evidence, the moral value of such work is incalculable. But to be effective it must be done under proper conditions, systematically; the time devoted to the work must be adequate; I would even advocate that the subject be allowed to come before conventional geography and history and other unpractical subjects, assuming that the training is given in a practical way and with practical objects in view, not in the form of mere lessons learnt by rote; if taught in the form of mere didactic lessons it is as worthless as any other subject as mental discipline. Let me add that I would confine the teaching to a narrow range of problems but make it very thorough with reference to these.

Five-and-twenty years ago I made my appearance as an advocate of what has been dubbed the heuristic method—the method which entails putting the learner in the attitude of inquirer, in training the pupil to inquire always into the meaning of what is learnt. I believe it to be in principle the only true method of learning. The idea has found favour almost generally, but the progress made in applying it has been slight; and this was to be expected, as teachers were few and far between who could carry the method into execution; moreover, so few teachers will allow their pupils to learn: they are too impatient and insist on teaching them and on doing the work of teacher and learner—in fact, in these days, the learner is a rarity: examinations have almost destroyed the breed. If here you desire that your children shall grow up virile men and women with some honesty of purpose left in them, you will end and not mend a system which is sucking the very life-blood out of the youth in the Mother Country—you will insist that your children shall be taught little but learn much; that they do not go out into the world mere parrots.

When studied as a special subject, chemistry, in particular, is one of the studies which must be worked at long and persistently—mere technical skill counts for so much and so few seem to possess the ability to become skilful chemists; in no other science does the element of understanding and an indefinable power of appreciating the character of changes as they occur play so conspicuous a part—in no other science is the faculty of judgment more necessary. In practice, the chemist in works is constantly called upon to exercise his judgment—he is only too often called upon to judge from appearances of conditions which are deep-seated; he is everywhere the works physician, in fact. It is therefore necessary that he should be highly trained

[1] I should like to take this opportunity of saying that it is impossible to overrate the public value of the great work which Dr. Wiley has undertaken in the United States in endeavouring to secure the supply of food free from deleterious ingredients. At home we certainly need someone to preach a similar crusade and to free us from doctored infants' foods and the innumerable host of medicines by which even our fair fields are disfigured.

and thoroughly versed in the art of inquiry. The men who in my experience have been successful are those who have learnt to think for themselves and who have been capable independent workers—sufficiently broad-minded and sufficiently practised in their art to be able to turn their attention in any desired direction; I should add that they have been men who have acquired that neglected art, the art of reading. Much has been said and written of late on the subject of technical training which is of value as bringing out the various points of view; the problem is a very difficult one, owing to the great number of interests to be considered, and more especially the very uneven and often inferior quality of the material to be trained. The great danger of specialised technical training is the tendency to make it too narrow. Success in practice depends not merely on knowledge of subject but also, if not mainly, on the possession of certain human qualities which are not usually developed in the technical school and which cannot be tested by examination. It is unnecessary to specify them. It is undeniable that in England for many years past chemistry has suffered from the recognised fact that there has been little money in it—parents have been led therefore to prefer other careers for their sons and the subject has not secured its due proportion of intelligence and is suffering in consequence. Too many of those who have entered works have had neither the intelligence nor—to speak plainly—the presence and manners that are required to secure confidence. The presence of men of gentlemanly bearing and instincts, who have received thorough training in science, is urgently needed at the present time in many of our manufacturing establishments, to take the place of foremen of the old type, who have learnt all they know in the works and whose conceptions necessarily lack breadth; it is almost impossible to convince such men that improvements are possible; too often they adopt a selfish attitude and advisedly retard progress. Another direction in which an approach of interests is required is between chemist and engineer. The latter has too long occupied a dominant position in many works, and in not a few cases has done his utmost to exclude the chemist, fearing his competition apparently. The gas industry perhaps affords the most striking illustration of the effects of such a policy: on the engineering side it has been carried to a high pitch of perfection but on the chemical it has ever fallen, year after year, to a lower state; now the quality of coal gas is such, especially since the withdrawal of the sulphur clauses from the Acts of Parliament by which the industry is regulated, that gas is almost unusable.[1]

But the iron industry is an even more striking case. The appliances are wonderful examples of constructive skill but the engineer is clearly nonplussed when he seeks to understand the processes he nominally controls; the chemist has been kept so closely confined to his bench in the laboratory that he has had no proper opportunity of studying the processes of manufacture systematically. No systematic study of steel has yet been made! Considering the magnitude of the industry and its importance, our knowledge of the subject is phenomenally slight; what we do know

[1] Had not chemists entirely unconnected with the industry vastly improved the methods of burning it, gas would long since have fallen into disuse. At last, when almost too late, the industry is taking some notice of our science. It needs reformation and reorganisation root and branch. That an industry should exist whose business it is to sell, as the primary product of manufacture, so minor a constituent of coal as the gas we burn is an anachronism. We should gain vastly in our cities if we burnt soft coke instead of smoke-yielding coal. Lastly, it is now imperative that none of the valuable constituents of coal should be wasted. Combining these three considerations, it is obviously desirable that, in future, all coal should be coked and both gas and coke supplied to the public instead, whilst the valuable residuals are used in other ways. No improvement has been effected by municipalities who have taken over the supply of gas; in the public interest some of these might well initiate such a change as is here suggested.

of the relation of strength and structure to composition is due to the pioneer labours of the late distinguished Dr. Sorby—an amateur unconnected with the industry—and to a fruitful conjunction of the labours of engineers and chemists outside the works, who in self-protection have tested the materials before use.

In Germany the chemist and the engineer have been placed on an equality and required to work together, with results which are altogether satisfactory. We need to adopt a similar practice. Any attempt to fuse the two into one will meet with failure, I am persuaded; they are called upon to work from different points of view—they need to be in sympathy and to understand one another but their work is complementary. I have watched engineering students closely during years past and am satisfied that, on the average, they represent a type of mind different from that of the chemist—the tendency of the one is to be constructive and of the other to be reflective: the analytical work done by the chemist in the laboratory is but the means to an end in the same way that the work done by the engineer in the drawing office is. Our future engineers should study chemistry and chemists should study engineering, in order that they may understand one another and work together—not in order that they may supplant one another. The chemist has to some extent allowed himself to be pushed into the background—perhaps because the average chemist in the past has been too tame a person; moreover, being forced to work in his laboratory, he has had less opportunity of gaining freedom and breadth of outlook than the more fortunate engineer, whose work has carried him out into the world.

You will be wise in Canada if you take care to select no small number of your abler students—young men of promise physically as well as intellectually—and train them as chemists. Of late years attention has been called from every side to the inconsiderate manner in which raw materials, especially coal, iron and wood, are being used up in all civilised countries. It is difficult to interest the public in such a subject, as few can appreciate the consequences, owing to the general ignorance of science and to the existence of an optimistic belief in the power of scientific discovery. But nothing will compensate for the exhaustion of your coal and iron supplies. It is your bounden duty to economise these in every possible way. The chemist and engineer will be required to help you in effecting economies by improving present methods of treatment. But the further question arises whether it be not also your duty, here in Canada particularly, without loss of time, to effect still greater economies by utilising the vast stores of energy in your possession, in the form of uplifted water, which now run to waste. The falls of Niagara are the most glorious and entrancing sight in the world I have witnessed next to the total eclipse of the sun, yet I question whether it be permissible to allow any part of their available energy to be dissipated—whether the claims of posterity do not forbid us to allow æsthetic considerations to prevail in such a case.

To conclude, I have treated my subject very widely and at times vaguely, having ranged over a great variety of subjects—somewhat from the point of view of modern opera, perhaps; indeed, I am willing to confess that I have been much influenced of late years by music and by the recognition of the obvious desire reflective musicians have shown to secure breadth of effect and harmonious development of all the elements which go to compose a dramatic situation. Chemistry touches the drama of life at every point: if ever we are to understand life and regulate our actions in accordance with understanding, it will be in no slight measure because we appreciate the lessons which chemistry alone affords.

The following Papers and Reports were then read:—

1. *Molecular Rearrangements in the Camphor Series.* *By* Professor William A. Noyes, *Ph.D.*

A study of some of the molecular rearrangements in the camphor series has been undertaken, in the hope that some additional light may be thrown on the mechanism of chemical reactions. It was pointed out that in the formation of cymene and of acetoorthoxylene from camphor the carbon atoms separate in a position with reference to the carbonyl group similar to that in the decomposition of acetoacetic ester. The formation of laurolene from aminolauronic acid was also discussed in the light of the structure as recently established by the author and Mr. Dirsch.

---

2. *Combustion.* *By* Professor W. A. Bone, *D.Sc.*, *F.R.S.*

---

3. *The Atomic Weight of Iridium. The Analysis of Potassium Chloroiridate.* *By* E. H. Archibald.

Potassium chloroiridate has been prepared from two sources: (1) from 150 gms. of osmo-iridium ore obtained from Messrs. Baker & Co., of Newark, N.J.; (2) from metallic iridium obtained from Dr. Heraeus, of Hanau.

The potassium chloroiridate was analysed by weighing the dry salt, reducing it in hydrogen and estimating the hydrochloric acid formed, the potassium chloride and the metallic iridium set free. The results show a value of 192.90 for the atomic weight of iridium.

---

4. *The Electrical Conductivity of Solutions of Iodine and of Platinum Tetraiodide in Ethyl Alcohol.* *By* E. H. Archibald *and* W. A. Patrick.

When solutions of iodine in ethyl alcohol were examined as to their power of conducting the electric current, it was found that the conductivity increased rapidly with the time. This change appeared to be due to the progress of a reaction, the speed of which was greatly accelerated, at low temperatures, by the platinum black of the electrodes. At 25° the conductivity reaches a maximum in about 25 hours. The reaction goes on extremely slowly if platinum black is not present. As a result of this reaction the colour of the solution becomes lighter. The initial conductivity of the iodine-alcohol solution was very small. No evidence could be found of the formation of an addition compound between the iodine and alcohol at as low a temperature as −80°.

Platinum tetraiodide forms good conducting solutions with alcohol. The molecular conductivity soon reaches a constant value.

---

5. *Anti-putrescent Effects of Copper Salts.* *By* Dr. Alfred Springer.

The peculiar behaviour of a Cincinnati certified milk in not becoming putrescent aroused the suspicion that it contained some antiseptic. The members of the Milk Commission insisted that they had not been lax in their supervision, that frequent and unannounced visits had been made to the dairy, and that all conditions surrounding the place, the cattle, the methods employed were in every sense exemplary; moreover, that the milk

had frequently been examined by their bacteriologist and chemist; they consequently felt convinced that no antiseptic could have been added. The dairymen indignantly denied having tampered with the milk, and claimed to have used every known precaution to make their certified milk the best in the market. We found, after long investigation, variable minute quantities of copper in the bottles of certified milk examined. In tracing the origin of the copper salts it developed that the boiler compound (used on account of the hard water) primed or foamed over, thereby contaminating the sterilising cloths, pails, and other utensils which came in contact with the milk. In order to find out if such minute quantities of copper could alter the milk, check experiments with and without the addition of copper salts were made; also differences in the behaviour of the same milk caught direct in broad-mouthed bottles and that obtained at the dairy in the usual mode of procedure were observed. Experiments showed that copper salts are selective in their actions, either greatly retarding or inhibiting the putrefactive bacteria, such as *Proteus vulgaris*, *mirabilis*, *Zenkeri* and *Clostridium fœtidum*, but, on the other hand, having but little effect upon the *Lactic bacteria*; consequently milk treated with these salts retained its sweet odour even if the acidity contents became sufficiently high to curd it.

Moulds such as *Penicillium glaucum*, *Aspergillus niger*, *Eurotium repens*, and others, probably because left a freer field for development, grow much more profusely upon the certified milk than on other milks not treated with copper salts. Tests with copper salts clearly demonstrated their antiputrescent effect in blood albumin, egg albumin, meat, milk, and sewage solutions. Even after nine months' submersion in dilute copper solutions there was no great change in the taste and odour of eggs, and, though left in the same position, the yolks did not adhere to the shells.

---

6. *Report on the Study of Isomorphous Sulphonic Derivatives of Benzene.*—See Reports, p. 141.

---

7. *Report on Electroanalysis.*—See Reports, p. 144.

---

8. *Report on the Study of Hydro-aromatic Substances.* See Reports, p. 145.

---

9. *Report on the Transformation of Aromatic Nitroamines and Allied Substances, and its Relation to Substitution in Benzene Derivatives.*—See Reports, p. 147.

FRIDAY, AUGUST 27.

Joint Meeting with Section A.[1]

The following Report and Papers were read:—

1. *Report on Dynamic Isomerism.*—See Reports, p. 135.

---

2. *On the Constancy of the Hydrogen Gas Electrode.* *By* CHARLES J. J. FOX, *B.Sc.*, *Ph.D.*

The author has investigated the constancy of the hydrogen gas electrode in H_2SO_4 and HCl, when gold, platinum, and palladium coated with

[1] See also Section A, p. 394.

platinum black and with palladium black are employed. Palladium coated with palladium black gives in both $0.1nH_2SO_4$ and $0.1n$HCl a value 4 to 5 millevolts too high; which is permanent even when the hydrogen is allowed to pass over the electrode for hours. But gold and platinum coated with either platinum or palladium black give in a very few minutes in both HCl and H_2SO_4l, values concordant among themselves to probably less than 0·05 of a millevolt. A piece of gold or platinum wire is as good as a large piece of foil. It has usually been considered that the hydrogen gas electrode in $0.1n$HCl is not so constant as in $0.1nH_2SO_4$. But this does not seem to be the case; at all events if precautions against the possible presence of arsenic be taken. It seems probable from Bredig's work that the smallest trace of arsenic would 'poison' the platinum or palladium black, and according to Crookes[1] it is practically impossible to purchase HCl free from arsenic. When this is borne in mind it seems preferable to use $0.1n$HCl rather than H_2SO_4, because the dissociation constant is so much better known and the ions produced are so much simpler. It is not possible to get a good coating of platinum black on a very pure specimen of platinum foil if the platinum chloride solution employed be also very pure. A trace of lead acetate is usually added to the solution therefore, and it is necessary to remove every trace of this from the electrode after coating, or good values will be unobtainable. Heating in a solution of oxalic acid and then in nitric acid removes all lead quite satisfactorily.

---

3. *The Measurement of Rotatory Dispersion.* *By* T. Martin Lowry, *D.Sc.*

Measurements have been made with light of the following twenty-six wave-lengths:

Li	**6708**	Na	**5893**	Tl	5351	(flame spectra).			
Hg	5790	5769	**5461**	**4359**	(enclosed arc).				
Cd	**6438**	**5086**	**4800**	4678	Zn	6364	4811	4722	4680.
Cu	5782	5700	5218	5153	5106	4705	4651	4587	4378.

A photographic method has also been devised by means of which measurements may be made throughout the transmitted spectrum, so far as this can be recorded on a photographic plate.

From the above list the seven wave-lengths shown in heavy type have been selected for general use, the green mercury line, Hg 5461, being selected on account of its brilliance and purity as principal standard in place of the sodium doublet, 5890 5896.

Measurements have been made of the optical and magnetic rotations produced by quartz and by a series of optically active alcohols, acids, and esters. In the case of quartz there is an absolute agreement between the two dispersions, but every optically active liquid that has been examined shows a divergence between the two series of values, the optical dispersion being usually, but not always, higher than the magnetic dispersion. It is possible that the identity of the optical and magnetic dispersions in crystals is an indication that the *magnetic* rotatory power of liquids depends upon a spiral packing of the molecules of the same general character as that which produces the *optical* rotatory power of quartz, but the evidence at present available is not sufficient to justify a definite pronouncement.

---

4. *Mercurous Sulphate for Standard Cells.* *By* Charles J. J. Fox, *B.Sc., Ph.D.*

It is now well established that the chief cause of inconstancy in cadmium cells is usually due to irregularities in the mercurous sulphate. F. E. Smith

[1] *Select Methods of Analysis*, 1905, p. 564.

has investigated this matter pretty exhaustively,[1] and has suggested four different methods for preparing reliable Hg_2SO_4.[2] The author wishes to suggest a fifth method which he has used, and which for simplicity and reliability seems to be superior to any of them.

There is no difficulty in purchasing Hg_2SO_4 which is quite free from foreign metals. But these commercially pure preparations, taken as they are, are unsuitable for use in standard cells because they have usually been precipitated from the nitrate solution in the cold, and are therefore not well crystallised; free nitrate and basic sulphate are also present. But if commercially pure Hg_2SO_4 be heated together with a little pure Hg and dilute H_2SO_4 for a day or so at 120° to 150° in either a sealed tube (1 to 2 millimetre walled tubing) or bottle with wire-bound stopper, and occasionally agitated, a white crystalline preparation will be obtained even from a specimen of Hg_2SO_4 which is initially discoloured almost black. On opening the tube or bottle it will usually be noticed that the pressure has risen a little, and that there is a trace of NO_2 formed; a little care should therefore be employed if there is more than a trace of nitrate in the original Hg_2SO_4. But the Hg_2SO_4 obtained in this way is itself free from nitrate, and especially if the H_2SO_4 be filtered off and renewed during the heating process; it is also, of course, quite free from basic salt. It is filtered off, ground up in a mortar with one or two successive quantities of diluted H_2SO_4, and then with several quantities of saturated cadmium sulphate solution; it is filtered off in a Büchner funnel after each washing. In this way it is possible with very little trouble to prepare quite large quantities of very reliable, well crystallised, white Hg_2SO_4 in every way suitable for standard cells.

Heating with HCl and Hg is also a very convenient method of preparing crystalline calomel; but in this case the heating takes about twice as long owing to the small solubility of calomel compared with Hg_2SO_4.

---

5. *A New Method of producing a Cadmium Arc.* *By* T. Martin Lowry, *D.Sc.*

In order to produce a cadmium spectrum of sufficient intensity for polarimetric work advantage is taken of the favourable properties of the silver-cadmium alloys. On account of their isomorphism the two metals form an excellent series of alloys which are characterised by good mechanical properties and very high melting points. (An alloy with 60 per cent. Cd melts as high as 700° C.) In striking contrast to the behaviour of the pure metal the alloy gives a steady arc which can be kept true to centre by rotating the electrodes in opposite directions. The spectrum shows the silver as well as the cadmium lines, but these are so far separated that even with a low resolving power the slit of a spectroscope can be opened to its full width without any overlapping of the brilliant 'blocks' of light which take the place of the usual 'lines.'

---

6. *Mercury and Cadmium Lines as Standards in Refractometry.* *By* T. Martin Lowry, *D.Sc.*

The series of wave-lengths commonly employed in refractometry—

$H\alpha$	Na	$H\beta$	$H\gamma$
6560	5893	4861	4341
red	yellow	blue	violet

is unsuited for general use in optical measurements on account of the

[1] F. E. Smith, *B.A. Report*, Cambridge, 1904, p. 33.
[2] F. E. Smith, *B.A. Report*, South Africa, 1905, p. 98.

dual character of the sodium light, which forms the principal standard, and the extreme feebleness of the hydrogen lines, which are used as 'secondary standards' when dispersive coefficients are required. In order to secure a proper correlation of optical measurements of various kinds it is suggested that the above series should be abandoned in favour of lines selected from the series—

Li	Cd	Na	Hg	Cd	Cd	Hg
6708	6438	5893	5461	5086	4800	4359

the green mercury line replacing the sodium doublet as 'principal standard.' In the measurement of rotatory dispersion it has been found that the ratio Hg 4359 to Hg 5461 is sufficient to characterise the dispersive power of a substance; in refractometry similar conditions may be expected to prevail, and it is pointed out that these two lines can be read even more easily than the hydrogen lines which they displace by using a vacuum tube containing a drop of mercury and gently warmed by means of a flame. If additional data are desired, the cadmium lines can be read with great readiness by employing a tiny silver-cadmium arc, or the sodium and lithium lines may be read in the ordinary way by making use of their flame spectra.

MONDAY, AUGUST 30.

Joint Discussion with Section K and Sub-Section K (Agriculture) on Wheat.—See Appendix A.

TUESDAY, AUGUST 31.

Joint Discussion with Section I on the Chemistry of Food. Opened by Professor H. E. Armstrong, *F.R.S.*

(i) *Proteins: the Relations between Composition and Food Value. By* E. Frankland Armstrong, *Ph.D., D.Sc.*

It has been customary hitherto, when investigating the protein content of a food material, to determine the amount of nitrogen in it and multiply this by the factor 6¼. The quotient is spoken of as protein without any reference to its nature, although it has long been realised that proteins of different origin are not the same. The practice was perhaps justifiable so long as the chemistry of the proteins remained an almost unexplored field; recent work, in particular that of Emil Fischer, Abderhalden, Osborne, and others, makes it possible to take up a more scientific position.

The proteins have been proved in the main to be built up of amino acids belonging both to the aliphatic and aromatic series or derived from cycloids containing nitrogen, of oxyamino acids and of diamino acids. The careful analytical investigation of a large number of proteins has shown that these various structural units are present in very different proportions in the different proteins; some of them may be altogether absent from a particular protein. Cereal proteins, for example, are characterised by a high percentage of glutamic acid, amounting to about 30 per cent. in most cases, the legumes yield about 20 per cent., oil seeds about 17 per cent.; meat proteins give only 8-11 per cent. glutamic acid but are characterised by containing much glycine.

The amino acids are so very different from one another in their chemical

structure that it must be supposed that they each fulfil somewhat different functions in building up the tissues of the body. It thus becomes important to see that each is supplied in the proper proportions required by the body. Further, the analytical results point to the impossibility of entirely substituting for a diet composed of one kind of protein—for example, meat—another diet composed, let us say, of nuts, since the two proteins, though made up of the same structural units, contain these in entirely different proportions.

Under the influence of the digestive enzymes the proteins can be converted into the same amino acids as are obtained when mineral acids are used to effect hydrolysis. If, however, the process of 'breaking-down' be stopped before completion, compounds in which two or more amino acids are joined together—the so-called polypeptides—can be isolated.

It remains now for the chemist and physiologist to ascertain the precise function and significance of each amino acid in metabolism; how far they may take the place of one another or may be absent without injurious effects; further, to what extent each is concerned in the maintenance of a particular tissue. Judging from the great variety of proteins consumed in a normal diet, it is obvious that every one of the units at present known to us must be of importance; a diet composed of one source of protein only or one which is too monotonous in character, even if derived from three or four different sources, is certainly to be condemned. Either will lead to the presence of an excess of particular amino acids and a deficiency of others perhaps equally important. All the evidence afforded by the chemical structure of the proteins goes, in fact, to show that they are not equivalent.

Probably the presence of most, if not all, of the various known amino acids and other units of protein is necessary in a food if health is to be maintained. In this connection some experiments of Willcock and Hopkins [1] may be cited, in which it was shown that young mice fed with zein as their only source of nitrogen soon died. When tryptophane, a unit which is absent in zein, was also administered, life was greatly prolonged; the addition of tyrosine—which, however, is a normal constituent of zein—had no such effect. Apparently the presence of some tryptophane is essential.

Some recent investigations of Abderhalden,[2] which possess considerable interest, may be quoted in illustration of the method of attack which will no doubt have to be followed in similar cases. As already indicated, it is a moot question whether the amino acids can be changed in nature or in amount or synthesised from simpler fractions in the organism; to answer it a study has been made of the silkworm, in which the problem is simplified by the fact that the worm takes no nourishment after it has begun to spin. The protein fibroin obtained from raw silk is characterised by yielding a large proportion of glycine and alanine and a fair proportion of tyrosine when hydrolysed; it is not without interest that both Italian and Canton silks are identical as regards the proportions of monoamino acids they contain. Silkworms, when dried and hydrolysed in the same manner as fibroin, were found to contain large supplies of the very amino acids most abundant in the silk fibroins.[3] The worm gives rise to cocoon and moth. Continuing the investigation, the moths were likewise subjected to analysis. The amount of glycine, alanine and tyrosine from them was very sensibly less and the yields of the other amino acids correspondingly higher than from the cocoons; in fact, the monoamino acids

[1] Willcock and Hopkins, *J. Physiol.* 1906, *35*, 83-102.

[2] Abderhalden, *Z. Physiol. Chem.* 1909, *58*, 334-340; *ibid.* *59*, 170-176; 236-238.

[3] It does not, however, necessarily follow that the worm contains ready-formed silk protein in the liquid state.

obtained from the moths were equivalent in amount to those from the worms minus those from the cocoons. To complete the story, it obviously remains to investigate the nature and quantity of the monoamino acids present in the proteins of the mulberry leaves which serve as food to the worms; Professor Abderhalden's further results will be awaited with interest.

In comparing proteins it is not enough to establish the nature and amount of the structural units, but it is necessary further to study how the monoamino acids are coupled together to di- and poly-peptides. Any pair of amino acids can give rise to two isomeric dipeptides with different physiological properties. The dipeptide glycylalanine, for example, behaves quite differently towards digestive enzymes than does the isomeric alanyl-glycine. Presumably a food containing the former would be less easily assimilated than one yielding the latter complex. This part of the subject is as yet in its infancy but it may be expected to yield results of great significance.

To sum up, when discussing the value of foods it is not enough to know merely the gross amount of nitrogen containing matter, but the nature and proportion of its constituent units must also be taken into account. The ideal diet should contain as great a variety of proteins as possible in order to provide a sufficient amount of all the required units of constructive metabolism.

(ii) *Some Physiological Problems in Agriculture.* *By* E. J. Russell, *D.Sc.*

(iii) *Economic Aspects of Cattle Feeding.* *By* Professor J. Wilson, *M.A.*, *B.Sc.*

Section C.—GEOLOGY.

President of the Section.—Dr. A. Smith Woodward, F.R.S.

THURSDAY, AUGUST 26.

The President delivered the following Address:—

The circumstances of the present Meeting very clearly determine the subject of a general address to be expected from a student of extinct animals. The remarkable discoveries of fossil backboned animals made on the North American continent during the last fifty years suggest an estimate of the results achieved by the modern systematic methods of research; while the centenary celebration of the birth of Darwin makes it appropriate to consider the extent to which we may begin deducing the laws of organic evolution from the life of past ages as we now know it. Such an address must, of course, be primarily biological in character, and treat of some matters which are not ordinarily discussed by Section C. The subject, however, can only be appreciated fully by those who have some practical acquaintance with the limitations under which geologists pursue their researches, and especially by those who are accustomed to geological modes of thought.

There has been an unfortunate tendency during recent years for the majority of geologists to relinquish the study of fossils in absolute despair. More ample material for examination and more exact methods of research have altered many erroneous names which were originally used; while the admission to scientific publications of too many mere literary exercises on the so-called 'law of priority' has now made it necessary to learn not one, but several names for some of the genera and species which are commonly met with. Even worse, the tentative arrangement of fossils in 'genetic series' has led to the invention of a multitude of terms which often serve to give a semblance of scientific exactitude to the purest guesswork, and sometimes degenerate into a jargon which is naturally repellent to an educated mind. Nevertheless, I still hope to show that, with all these difficulties, there is so much of fundamental interest in the new work that it is worth while to make an effort to appreciate it. Geology and palæontology in the past have furnished some of the grandest possible contributions to our knowledge of the world of life; they have revealed hidden meanings which no study of the existing world could even suggest; and they have started lines of inquiry which the student of living animals and plants alone would scarcely have suspected to be profitable. The latest researches are the logical continuation of this pioneer work on a more extensive scale, and with greater precision; and I am convinced that they will continue to be as important a factor in the progress of post-Darwinian

biology as were the older studies of fossils in the philosophy of Cuvier, Brongniart, and Owen.

In this connection it is necessary to combat the mistaken popular belief that the main object of studying fossils is to discover the 'missing links' in the chain of life. We are told that the idea of organic evolution is not worthy of serious consideration until these links, precise in character, are forthcoming in all directions. Moreover, the critics who express this opinion are not satisfied to consider the simplest cases, such as are afforded by some of the lower grades of 'shell-fish' which live together in immense numbers and have limited powers of locomotion. They demand long series of exact links between the most complex skeletal frames of the backboned animals, which have extreme powers of locomotion, are continually wandering, and are rarely preserved as complete individuals when they are buried in rock. They even expect continual discoveries of links among the rarest of all fossils, those of the higher apes and man. The geologist, on the other hand, knowing well that he must remain satisfied with a knowledge of a few scattered episodes in the history of life which are always revealed by the merest accident, marvels that the discovery of 'missing links' is so constant a feature of his work. He is convinced that, if circumstances were more favourable, he would be able to satisfy the demand of the most exacting critic. He has found enough continuous series among the mollusca, for example, and so many suggestions of equally gradual series among the higher animals, that he does not hesitate to believe without further evidence in a process of descent with modification. The mere reader of books is often misled by the vagaries of nomenclature to suppose that the intervals between the links are greater than they are in reality; but for the actual student it is an everyday experience to find that fossils of slightly different ages which he once thought distinct are linked together by a series of forms in which it is difficult to discover the feeblest lines of demarcation. He is therefore justified in proceeding on the assumption that in all cases the life of one geological period has passed by a natural process of descent into that of the next succeeding period; and, avoiding genealogical guesswork which proves to be more and more futile, he strives to obtain a broad view of the series of changes which have occurred, to distinguish between those which denote progress and those which lead to stagnation or extinction. When the general features of organic evolution are determined in this manner, it will be much easier than it is at present to decide where missing links in any particular case are most likely to be found.

Among these general features which have been made clear by the latest systematic researches, I wish especially to emphasise the interest and significance of the persistent progress of life to a higher plane, which we observe during the successive geological periods. For I think palæontologists are now generally agreed that there is some principle underlying this progress much more fundamental than chance-variation or response to environment, however much these phenomena may have contributed to certain minor adaptations. Consider the case of the backboned animals, for instance, which I happen to have had special opportunities of studying.

We are not likely ever to discover the actual ancestors of animals on the backboned plan, because they do not seem to have acquired any hard skeleton until the latter part of the Silurian period, when fossils prove them to have been typical and fully developed, though low in the backboned scale. The ingenious researches and reasoning of Dr. W. H. Gaskell, however, have suggested the possibility that these animals originated from some early relatives of the scorpions and crustaceans. It is therefore of great interest to observe that the Eurypterids and their allies, which occupy this zoological position, were most abundant during the Silurian period, were represented by species of the largest size immediately afterwards at the beginning of the Devonian, and then gradually dwindled into insignifi-

cance. In other words, there was a great outburst of Eurypterid life just at the time when backboned animals arose; and if some of the former were actually transformed into the latter, the phenomenon took place when their powers both of variation and of multiplication were at their maximum.

Fishes were already well established and distributed over perhaps the greater part of the northern hemisphere at the beginning of Devonian times; and then there began suddenly a remarkable impulse towards the production of lung-breathers, which is noticeable not only in Europe and North America, but also probably so far away as Australia. In the middle and latter part of the Devonian period most of the true fishes had paddles, making them crawlers as much as swimmers; many of them differed from typical fishes, while agreeing with lung-breathers in having the basis of the upper jaw fused with the skull, not suspended; and some of them exhibited both these features. Their few survivors at the present day (the Crossopterygians and Dipnoans) have also an air-bladder, which might readily become a lung. The characteristic fish-fauna of the Devonian period, therefore, made a nearer approach to the land animals than any group of fishes of later date; and it is noteworthy that in the Lower Carboniferous of Scotland—perhaps even in the Upper Devonian of North America, if footprints can be trusted—amphibians first appeared. In Upper Carboniferous times they became firmly established, and between that period and the Trias they seem to have spread all over the world; their remains having been found, indeed, in Europe, Spitzbergen, India, South Africa, North and South America, and Australia.

The Stegocephala or Labyrinthodonts, as these primitive amphibians are termed, were therefore a vigorous race; but the marsh-dwelling habits of the majority did not allow of much variation from the salamander pattern. Only in Upper Carboniferous and Lower Permian times did some of their smaller representatives (the Microsauria) become lizard-like, or even snake-like in form and habit; and then there suddenly arose the true reptiles. Still, these reptiles did not immediately replace the Stegocephala in the economy of Nature; they remained quite secondary in importance at least until the Upper Permian, in most parts even until the dawn of the Triassic period. Then they began their flourishing career.

At this time the reptiles rapidly diverged in two directions. Some of them were almost exactly like the little *Sphenodon*, which still survives in some islands off New Zealand, only retaining more traces of their marsh-dwelling ancestors. The majority (the Anomodonts or Theromorphs) very quickly became so closely similar to the mammals that they can only be interpreted as indicating an intense struggle towards the attainment of the higher warm-blooded grade; and there is not much doubt that true mammals actually arose about the end of the Triassic period. Here again, however, the new race did not immediately replace the old, or exterminate it by unequal competition. Reptiles held their own on all lands throughout the Jurassic and Cretaceous periods, and it was not until the Tertiary that mammals began to predominate.

As to the beginning of the birds, it can only be said that towards the end of the Triassic period there arose a race of small Dinosaurs of the lightest possible build, exhibiting many features suggestive of the avian skeleton; so it is probable that this higher group also originated from an intensely restless early community of reptiles, in which all the variations were more or less in the right direction for advancement.

In short, it is evident that the progress of the backboned land animals during the successive periods of geological time has not been uniform and gradual, but has proceeded in a rhythmic manner. There have been alternations of restless episodes which meant real advance, with periods of comparative stability, during which the predominant animals merely varied in response to their surroundings, or degenerated, or gradually grew

to a large size. There was no transition, for instance, between the reptiles of the Cretaceous period and the mammals which immediately took their place in the succeeding Eocene period: those mammals, as we have seen, had actually originated long ages before, and had remained practically dormant in some region which we have not yet discovered, waiting to burst forth in due time. During this retirement of the higher race the reptiles themselves had enjoyed an extraordinary development and adaptation to every possible mode of life in nearly all parts of the globe. We do not understand the phenomenon—we cannot explain it; but it is as noticeable in the geological history of fishes as in that of the land animals just considered. It seems to have been first clearly observed by the distinguished American naturalist, the late Professor Edward D. Cope, who termed the sudden fundamental advances 'expression points,' and saw in them a manifestation of some inscrutable inherent 'bathmic force.'

Perhaps the most striking feature to be noticed in each of these 'expression points' is the definite establishment of some important structural character which had been imperfect or variable before, thus affording new and multiplied possibilities of adaptation to different modes of life. In the first lung-breathers (Stegocephala), for example, the indefinite paddle of the mud fishes became the definite five-toed limb; while the incomplete backbone reached completeness. Still, these animals must have been confined almost entirely to marshes, and they seem to have been all carnivorous. In the next grade, that of the reptiles, it became possible to leave the marshes; and some of them were soon adapted not only for life on hard ground or in forests, but even for flight in the air. Several also assumed a shape of body and limbs enabling them to live in the open sea. Nearly all were carnivorous at first, and most of them remained so to the end; but many of the Dinosaurs eventually became practically hoofed animals, with a sharp beak for cropping herbage, and with powerful grinding teeth. In none of these animals, however, were the toes reduced to less than three in number, and in none of them were the basal toe-bones fused together as they are in cattle and deer. It is also noteworthy that the brain in all of them remained very small and simple. In the final grade of backboned life, that of the mammals, each of the adaptive modifications just mentioned began to arise again in a more nearly perfected manner, and now survival depended not so much on an effective body as on a developing brain. The mammals began as little carnivorous or mixed-feeding animals with a small brain and five toes, and during the Tertiary period they gradually differentiated into the several familiar groups as we now know them, eventually culminating in man.

The demonstration by fossils that many animals of the same general shape and habit have originated two or three times, at two or three successive periods, from two or three continually higher grades of life, is very interesting. To have proved, for example, that flying reptiles did not pass into birds or bats, that hoofed Dinosaurs did not change into hoofed mammals, and that Ichthyosaurs did not become porpoises; and to have shown that all these later animals were mere mimics of their predecessors, originating independently from a higher yet generalised stock, is a remarkable achievement. Still more significant, however, is the discovery that towards the end of their career through geological time totally different races of animals repeatedly exhibit certain peculiar features, which can only be described as infallible marks of old age.

The growth to a relatively large size is one of these marks, as we observe in the giant Pterodactyls of the Cretaceous period, the colossal Dinosaurs of the Upper Jurassic and Cretaceous, and the large mammals of the Pleistocene and the present day. It is not, of course, all the members of a race that increase in size; some remain small until the end, and they generally survive long after the others are extinct; but it is nevertheless

a common rule that the prosperous and typical representatives are successively larger and larger, as we see them in the familiar cases of the horses and elephants of the northern hemisphere and the hoofed animals and armadillos of South America.

Another frequent mark of old age in races was first discussed and clearly pointed out by the late Professor C. E. Beecher, of Yale. It is the tendency in all animals with skeletons to produce a superfluity of dead matter, which accumulates in the form of spines or bosses as soon as the race they represent has reached its prime and begins to be on the down-grade. Among familiar instances may be mentioned the curiously spiny Graptolites at the end of the Silurian period, the horned Pariasaurians at the beginning of the Trias, the armour-plated and horned Dinosaurs at the end of the Cretaceous, and the cattle or deer of modern Tertiary times. The latter case—that of the deer—is specially interesting, because fossils reveal practically all the stages in the gradual development of the horns or antlers, from the hornless condition of the Oligocene species, through the simply forked small antlers of the Miocene species, to the largest and most complex of all antlers seen in *Cervus sedgwicki* from the Upper Pliocene and the Irish deer (*C. giganteus*) of still later times. The growth of these excrescences, both in relative size and complication, was continual and persistent until the climax was reached and the extreme forms died out. At the same time, although the palæontologist must regard this as a natural and normal phenomenon not directly correlated with the habits of the race of animals in which it occurs, and although he does not agree with the oft-repeated statement that deer may have 'perfected' their antlers through the survival of those individuals which could fight most effectively, there may nevertheless be some truth in the idea that the growths originally began where the head was subject to irritating impacts and that they so happened to become of utility. Fossils merely prove that such skeletal outgrowths appear over and over again in the prime and approaching old age of races; they can suggest no reasons for the particular positions and shapes these outgrowths assume in each species of animal.

It appears, indeed, that when some part of an animal (whether an excrescence or a normal structure) began to grow relatively large in successive generations during geological time, it often acquired some mysterious impetus by which it continued to increase long after it had reached the serviceable limit. The unwieldy antlers of the extinct Sedgwick's deer and Irish deer just mentioned, for example, must have been impediments rather than useful weapons. The excessive enlargement of the upper canine teeth in the so-called sabre-toothed tigers (*Machærodus* and its allies) must also eventually have hindered rather than aided the capture and eating of prey. The curious gradual elongation of the face in the Oligocene and Miocene Mastodons, which has lately been described by Dr. Andrews, can only be regarded as another illustration of the same phenomenon. In successive generations of these animals the limbs seem to have grown continually longer, while the neck remained short, so that the head necessarily became more and more elongated to crop the vegetation on the ground. A limit of mechanical inefficiency was eventually reached, and then there survived only those members of the group in which the attenuated mandible became shortened up, leaving the modified face to act as a 'proboscis.' The elephants thus arose as a kind of after-thought from a group of quadrupeds that were rapidly approaching their doom.

The end of real progress in a developing race of backboned animals is also often marked by the loss of the teeth. A regular and complete set of teeth is always present at the commencement, but it frequently begins to lack successors in animals which have reached the limit of their evolution, and then it soon disappears. Tortoises, for instance, have been toothless since the Triassic period, when they had assumed all their essential

features; and birds have been toothless since the end of Cretaceous times. The monotreme mammals of Australasia, which are really a survival from the Jurassic period, are also toothless. Some of the latest Ichthyosaurs and Pterodactyls were almost or quite toothless; and I have seen a jaw of an Upper Cretaceous carnivorous Dinosaur (*Genyodectes*) from Patagonia so completely destitute of successional teeth that it seems likely some of these land reptiles nearly arrived at the same condition.

Among fishes there is often observable still another sign of racial old age—namely, their degeneration into eel-shaped forms. The Dipnoan fishes afford a striking illustration, beginning with the normally shaped *Dipterus* in the Middle Devonian, and ending in the long-bodied *Lepidosiren* and *Protopterus* of the present day. The Palæozoic Acanthodian sharks, as they are traced upwards from their beginning in the Lower Devonian to their end in the Permian, also acquire a remarkable elongation of the body and a fringe-like extension of the fins. Among higher fishes, too, there are numerous instances of the same phenomenon, but in most of these the ancestors still remain undiscovered, and it would therefore be tedious to discuss them.

Finally, in connection with these obvious symptoms of old age in races, it is interesting to refer to a few strange cases of the rapid disappearance of whole orders of animals, which had a practically world-wide distribution at the time when the end came. Local extinction, or the disappearance of a group of restricted geographical range, may be explained by accidents of many kinds; but contemporaneous universal extinction of widely spread groups, which are apparently not affected by any new competitors, is not so easily understood. The Dinosaurs, for instance, are known to have lived in nearly all lands until the close of the Cretaceous period; and, except perhaps in Patagonia, they were always accompanied until the end by a typically Mesozoic fauna. Their remains are abundant in the Wealden formation of Western Europe, the deposit of a river which must have drained a great continent at the beginning of the Cretaceous period; they have also been found in a corresponding formation which covers a large area in the State of Bahia, in Brazil. They occur in great numbers in the freshwater Upper Cretaceous Laramie deposits of Western North America, and also in a similar formation of equally late date in Transylvania, South-East Europe. In only two of these regions (South-East England and West North America) have any traces of mammals been found, and they are extremely rare fragments of animals as small as rats; so there is no reason to suppose that the Dinosaurs suffered in the least from any struggle with warm-blooded competitors. Even in Patagonia, where the associated mammal-remains belong to slightly larger and more modern animals, these fossils are also rare, and there is nothing to suggest competition. The race of Dinosaurs seems, therefore, to have died a natural death. The same may be said of the marine reptiles of the orders Ichthyosauria, Plesiosauria, and Mosasauria. They had a practically world-wide distribution in the seas of the Cretaceous period, and the Mosasauria especially must have been extremely abundant and flourishing. Nevertheless, at the end of Cretaceous times they disappeared everywhere, and there was absolutely nothing to take their place until the latter part of the Eocene period, when whales and porpoises began to play exactly the same part. So far as we know, the higher race never even came in contact with the lower race; the marine mammals found the seas vacant, except for a few turtles and for one curious Rhynchocephalian reptile (*Champsosaurus*), which did not long survive. Another illustration of the same phenomenon is probably afforded by the primitive Carnivora (the so-called Sparassodonta), which were numerous in South America in the Lower Tertiary periods. They were animals with a brain as small as that of the thylacines and dasyures which now live in Tasmania. They appear to have died out completely before they were

replaced by the cats, sabre-toothed tigers, and dogs, which came down south from North America over the newly emerged isthmus of Panama at the close of the Pliocene period. At least, the remains of these old carnivores and their immigrant successors have never yet been found associated in any geological formation.

These various considerations lead me to think that there is also deep significance in the tendency towards fixity in the number and regularity (or symmetry) in the arrangement of their multiple parts which we frequently observe in groups of animals as we trace them from their origin to their prime. It is well known that in certain of the highest and latest types of bony fishes the vertebræ and fin-rays are reduced to a fixed and practically invariable number for each family or genus, whereas there is no such fixity in the lower and earlier groups. In the earliest known Pycnodont fishes from the Lower Lias (*Mesodon*) the grinding teeth form an irregular cluster, while in most of the higher and later genera they are arranged in definite regular rows in a symmetrical manner. Many of the lower backboned animals have teeth with several cusps, and in some genera the number of teeth seems to be constant; but in the geological history of the successive classes the tooth-cusps never became fixed individual entities readily traceable throughout whole groups, until the highest or mammalian grade had been attained. Moreover, it is only in the same latest grade or class that the teeth themselves can be treated as definite units, always the same in number (forty-four), except when modified by degeneration or special adaptation. In the earlier and lower land animals the number of vertebræ in the neck depends on the extent of this part, whereas in the mammal it is almost invariably seven, whatever the total length may be. Curiously constant, too, in the modern even-toed hoofed mammals is the number of nineteen vertebræ between the neck and the sacrum.

I am therefore still inclined to believe that the comparison of vital processes with certain purely physical phenomena is not altogether fanciful. Changes towards advancement and fixity which are so determinate in direction, and changes towards extinction which are so continually repeated, seem to denote some inherent property in living things which is as definite as that of crystallisation in inorganic substances. The regular course of these changes is merely hindered and modified by a succession of checks from the environment and Natural Selection. Each separate chain of life, indeed, bears a striking resemblance to a crystal of some inorganic substance which has been disturbed by impurities during its growth, and has thus been fashioned with unequal faces, or even turned partly into a mere concretion. In the case of a crystal the inherent forces act solely on molecules of the crystalline substance itself, collecting them and striving, even in a disturbing environment, to arrange them in a fixed geometrical shape. In the case of a chain of life (or organic phylum) we may regard each successive animal as a temporary excrescence of colloid substance round the equally colloid germ-plasm which persists continuously from generation to generation. The inherent forces of this germ-plasm, therefore, act upon a consecutive series of excrescences (or animal bodies) struggling, not for geometrically arranged boundaries, but towards various other symmetries, and a fixity in number of multiple parts. When the extreme has been reached, activities cease, and sooner or later the race is dead.

Such are some of the most important general results to which the study of fossils has led during recent years; and they are conclusions which every new discovery appears to make more certain. When we turn to details, however, it must be admitted that modern systematic researches are continually complicating rather than simplifying the problems we have to solve. Professor Charles Depéret has lately written with scant respect of some of the pioneers who were content with generalities, and based their conclusions on the geological succession of certain anatomical structures rather than on

a successive series of individuals and species obtained from the different layers of one geological section; but even now I do not think we can do much better than our predecessors in unravelling real genealogies. At least Professor Depéret's genealogical table of the Lower Tertiary pig-like Anthracotheriidæ, which he publishes as an illustration of 'évolution réelle,' seems to me to be no more exact than several tables of other groups by previous authors which he criticises. His materials are all fragmentary, chiefly jaws and portions of skulls; they were obtained from several isolated lake-deposits, of which the relative age cannot be determined by observing the geological superposition; and they represent a group which is known to have lived over a large part of Europe, Asia, Northern Africa, and North America. There is therefore no certainty that the genera and species enumerated by Professor Depéret actually originated one from the other in the region where he happened to find them; he has demonstrated the general trend of certain changes in the Anthracotheriidæ during geological time, but really nothing more.

Even when a group of animals seems to have been confined to one comparatively small region, where the series is not complicated by migration to and from other parts of the world, modern research still emphasises the difficulty of tracing real lines of descent. The primitive horned hoofed animals of the family Titanotheriidæ, for example, are only known from part of North America, and they seem to have originated and remained there until the end. As their fossil skeletons are abundant and well preserved, it ought to be easy to discover the exact connections of the several genera and species. Professor Osborn has now proved, however, that the Titanotheres must have evolved in at least four distinct lines, adapted 'for different local habitat, different modes of feeding, fighting, locomotion, &c., which took origin, in part at least, in the Middle or Upper Eocene.' They exhibit 'four distinct types in the shape and position of the horns, correlated with the structure of the nasals and frontals, and indicative of different modes of combat among the males.' The ramifications of the group are indeed so numerous that the possibility of following chains of ancestors begins to appear nearly hopeless.

Among early reptiles the same difficulties are continually multiplied by the progress of discovery. About twenty years ago it began to appear likely that we should soon find the terrestrial ancestors of the Ichthyosauria in the Trias; and somewhat later a specimen from California raised hopes of obtaining them by systematic explorations in that region. During more recent years Professor J. C. Merriam and his colleagues have actually made these explorations, and the result is that we now know from the Californian Trias a multitude of reptiles, which need more explanation than the Ichthyosauria themselves. Professor Merriam has found some of the links predicted between Ichthyosaurs and primitive land reptiles, but he has by no means reached the beginning of the marine group; and while making these discoveries he has added greatly to the complication of the problem which he set out to solve.

Serious difficulties have also become apparent during recent years in determining exactly the origin of the mammals. For a long time after the discovery of the Anomodont or Theromorph reptiles in the Permian-Trias of South Africa, it seemed more and more probable that the mammals arose in that region. Even yet new reptiles from the Karoo formation are continually being described as making an astonishingly near approach to mammals; and, so far as the skeleton is concerned, the links between the two grades are now very numerous among South African fossils. Since these reptiles first attracted attention, however, they have gradually been found in the Permian and Trias of a large part of the world. Remains of them were first met with in India, then in North America, and next in Scotland, while during the last few years Professor W. Amalitzky has disinterred so many

nearly complete skeletons in the north of Russia that we are likely soon to learn more about them from this European country than from the South African area itself. Quite lately I have received numerous bones from a red marl in Rio Grande do Sul, Southern Brazil, which show that not merely Anomodonts, but also other characteristic Triassic land reptiles were likewise abundant in that region. We are therefore now embarrassed by the richness of the sources whence we may obtain the ancestors of mammals. Whereas some years ago it appeared sufficient to search South Africa for the solution of the problem, we are now uncertain in which direction to turn. We are still perhaps inclined to favour the South African source; but this is only because we know nothing of the Jurassic land animals of that part of the world, and we cherish a lingering hope that they may eventually prove to have included the early mammals for which we have so long sought in vain.

The mystery of the origin of the marine mammals of the order Sirenia and Cetacea appears to have been diminished by the discoveries of the Geological Survey of Egypt, Dr. Andrews, and Dr. Fraas in the Eocene and Oligocene deposits of the Mokattam Hills and the Fayum. It is now clear that the Sirenians are closely related to the small primitive ancestors of the elephants; while, so far as the skull and dentition are concerned, we know nearly all the links between the early toothed whales (or Zeuglodonts) and the primitive ancestors of the Carnivora (or Creodonts). The most primitive form of Sirenian skull hitherto discovered, however, is not from Egypt, but from the other side of the world, Jamaica; and exactly the same Zeuglodonts, even with an associated sea-snake, occur so far away from Egypt as Alabama, U.S.A. The problem of the precise origin of these marine mammals is therefore not so simple as it would have appeared to be had we known only the Egyptian fossils. The progress of discovery, while revealing many most important generalities, has made it impossible to vouch for the accuracy of the details in any 'genealogical tree.'

Another difficulty resulting from the latest systematic researches is suggested by the extinct hoofed mammals of South America. The llamas, deer, and peccaries existing in South America at the present time are all immigrants from the northern continent; but during the greater part of the Tertiary period there lived in that country a large number of indigenous hoofed mammals, which originated quite independently of those in other regions. They seem to have begun in early Eocene times much in the same manner as those of the northern hemisphere; but as they became gradually adapted for life on hard ground, they formed groups which are very different from those with which we are familiar in our part of the world. Some of them (Proterotheriidæ) were one-toed mimics of the horses, but without the advanced type of brain, the deepened grinding teeth, the mobile neck, or the really effective wrist and ankle. Others (Toxodontidæ) made some approach towards rhinoceroses in shape and habit, even with a trace of a horn on the nose. Until their independent origin was demonstrated, these curious animals could not be understood; and it is probable that there are innumerable similar cases of parallel development of groups, by which in our ignorance we are often misled.

It would be easy to multiply instances, but I think I have now said enough to show that every advance in the study of fossils reveals more problems than it solves. During the last two decades the progress in our knowledge of the extinct backboned animals has been truly astonishing, thanks especially to the great explorations in North America, Patagonia, Egypt, Madagascar, and South Africa. Whole groups have been traced a long way towards their origin; but with them have been found a number of previously unknown groups which complicate all questions of evolution to an almost bewildering extent. Animals formerly known only by fragments are now represented by nearly complete skeletons, and several which

appeared to have a restricted geographical range have now been found over a much wider area; but while this progress has been made, numerous questions have arisen as to the changing connections of certain lands and seas which previously seemed to have been almost settled. The outlook both of zoology and of geology has, therefore, been immensely widened, but the only real contribution to philosophy has been one of generalities. Some of the broad principles to which I have referred are now so clearly established that we can often predict what will be the main result of any given exploration, should it be successful in recovering skeletons. We are no longer bold enough to restore an entirely unknown extinct animal from a single bone or tooth, like the trustful Cuvierian school; but there are many kinds of bones and teeth of which we can determine the approximate geological age and probable associates, even if we have no exact knowledge of the animals to which they belong. A subject which began by providing material for wonder-books has thus been reduced to a science sufficiently precise to be of fundamental importance both to zoology and to geology; and its exactitude must necessarily increase with greater and greater rapidity as our systematic researches are more clearly guided by the experience we have already gained.

The following Papers were then read:—

1. *The Geology of Western Canada. By* J. B. Tyrrell, *M.A.*

Beginning at the Archæan granites and gneisses which outcrop about forty miles east of the City of Winnipeg, and, proceeding westward, flat-lying sandstones of Chazy age from 20 to 100 feet in thickness are first met with, overlying which are about 300 feet of Trenton limestones, in many places rich in fossils. The limestone so commonly used in the City of Winnipeg is from one of the higher beds in this formation.

These limestones are conformably overlain by reddish shaly beds, also rich in fossils, which here form the summit of the Ordovician series. These are well shown at Stony Mountain, a few miles north-west of this city.

Overlying these are about 100 feet of porous and cavernous dolomites, particularly interesting to the people of Winnipeg, as they are the rocks which carry the artesian water for the city from its high collecting ground between Lakes Winnipeg and Manitoba to the wells, from which it is pumped for the use of the citizens.

These rocks are shown in the quarry at Stonewall, but fossils are not at all common in it.

Overlying the Silurian dolomites are from 300 to 400 feet of shales, dolomites, and limestones of Devonian age.

All these beds, from the base of the Ordovician to the top of the Devonian, are conformable, and represent a continuous sedimentation, there being no break whatever in the series. It is not improbable that the series may even run up into the Carboniferous, but, if so, the higher Palæozoic rocks are now buried under later sediments.

After Devonian, or perhaps Carboniferous, times a period of erosion commenced, and continued until well on into the Cretaceous age, when the whole country from the edge of the Archæan westward was depressed beneath the ocean, and sandstones, and afterwards clays and calcareous shales, were deposited on its floor. These beds have been named in ascending order *Dakota*, *Benton*, *Niobrara*, *Pierre* (subdivided into *Millwood* and *Odanah* series, with the *Belly River* sandstones dividing it in the west), and *Laramie*.

The latter seems to be a transition series between the Cretaceous and Eocene, but it has been subdivided into a lower (Edmonton) formation

with a prominently Cretaceous fauna of Dinosaurs, &c., and an upper (Pascapo) formation with a prominently Eocene fauna and flora.

These Cretaceous and Eocene beds underlie the great plains from Portage la Prairie in the east to the foot-hills of the Rocky Mountains in the west, and throughout this distance they have a practically horizontal attitude. But they become thicker as they approach the Rocky Mountains.

At the eastern flank of the mountains they are broken by a great reverse fault, and are overridden by limestones, &c., of Devono-Carboniferous age, which thus form the eastern escarpment of the mountains, while farther west they are included in the folds of the mountains themselves. The great coal areas in the mountains are of Lower Cretaceous age.

Farther west, along the line of the Canadian-Pacific Railway through British Columbia, rocks of various ages, from Archæan up to Tertiary, may be seen; but it will be more interesting to point them out as we pass them on our special train than to attempt any description here.

---

2. *The Distribution of the Ice Sheets in Western Canada.* *By* Dr. A. P. Coleman.

The Ice Age began in Canada by the extension of mountain glaciers in the Cordilleran region till the valleys were occupied and the ice flowed out upon the plains. When this ice-sheet retreated, the ice began to spread from the Keewatin centre, covering the plains and reaching nearly the foot of the mountains. In former maps of the western glaciation a strip was left uncovered along the eastern edge of the mountains; but it has been found by recent work that this is not correct, since the older boulder clay from the mountains underlies the later till from the Keewatin Archæan region.

At present the Keewatin centre is 2,000 or 3,000 feet lower than the position of Archæan boulders in the foot-hills of the Rockies. The altitudes of the different areas may have been different when the Keewatin ice did its work, though the region was probably not at sea-level. Many of the far-western erratics were transported by floating ice on ice-dammed lakes during the retreat of the Keewatin Glacier.

---

3. *The Glacial Lake Agassiz.* *By* Warren Upham, *A.M.*, *D.Sc.*

During the final melting of the North American ice-sheet a glacial lake, held by its barrier in the basin of the Red River and Lake Winnipeg, extended from Lake Traverse, on the west side of Minnesota, northward to the Saskatchewan and Nelson Rivers, and eastward on the international boundary to and somewhat beyond Rainy Lake. It attained thus an area of about 110,000 square miles, exceeding the combined areas of the five great lakes tributary to the St. Lawrence River. This glacial lake, named in 1879 Lake Agassiz, had a southwardly flowing outlet, called the Glacial River Warren, which took the course of the present Minnesota River, joining the Mississippi at Fort Snelling.

Beach ridges of sand and gravel, a few feet high, traced by levelling along about 800 miles of the highest shore of Lake Agassiz, mark its stage of greatest extent; and other similar beaches, at many successive lower levels, record later stages of the lake, reduced in height by erosion of a deep channel along the course of the outflowing river. After the recession of the ice-sheet permitted drainage from the glacial lake north-eastward into Hudson Bay, still lower beaches were formed, until the complete uncovering of the area crossed by the Nelson River reduced Lake Agassiz finally to its present representative, Lake Winnipeg.

In its earliest and highest stage, Lake Agassiz was nearly 200 feet deep above Moorhead and Fargo; a little more than 300 feet deep above Grand Forks and Crookston; about 450 feet above Pembina, St. Vincent, and Emerson; more than 500 feet above the site of the city of Winnipeg; and about 500 and 600 feet respectively above Lakes Manitoba and Winnipeg. The length of Lake Agassiz is estimated to have been nearly 700 miles, and its greatest width more than 200 miles.

Reports on the explorations of this ancient lake have been published by the Geological Surveys of Minnesota, the United States, and Canada. In the present paper the latest explanations are reviewed to account for the northward ascent of its beaches.

The highest and earliest beach or shore-line has an ascent of about a foot per mile toward the north-north-east; the lower and later shores ascend less; and the lowest shore, marked by beaches only 60 to 70 feet above Lake Winnipeg, are almost perfectly horizontal. It is thus known that the land was being uplifted differentially while Lake Agassiz existed, and that the uplift was nearly completed before the ice-sheet was wholly melted away.

The chief cause of the uplift is thought to be the unburdening of the land by the removal of the vast weight of the ice-sheet, this part of the earth-crust being restored to equilibrium or isostasy by an inflow of the plastic magma at a great depth within the earth, which took place during the time of departure of the ice.

Measures of the shore erosion and beach accumulation indicate that the duration of Lake Agassiz was only about 1,000 years; and from the rate of recession of the Falls of St. Anthony, forming the gorge of the Mississippi River between Fort Snelling and Minneapolis, the length of the Postglacial period is estimated to be between 6,000 and 10,000 years.

4. *The Rainfall Run-off Ratio in the Prairies of Central North America.* *By* Professor E. F. Chandler.

A brief definition of terms was given in connection with the division of rainfall into 'evaporation' and 'run-off.' The river-flow, or run-off, is the residual remaining from the total precipitation after the demands of evaporation and plant-growth are supplied.

A summary was furnished of results secured from the systematic measurements of the rivers of the northern United States that have been maintained continuously for the past six years. In the Red River valley prairies the mean annual rainfall is from 15 to 25 inches. Evaporation from the soil and from vegetation consumes here nearly the whole of the rainfall; the remainder that enters the streams is but a small fraction—3 to 20 per cent. of the whole—its amount depending on the quantity and distribution of the rainfall. This condition was contrasted with other regions where the rainfall is greater so that the run-off is half or three-fourths or more of the rainfall, or where the precipitation is less fortunately distributed through the seasons so that vegetation is unable to secure so great a portion.

FRIDAY, AUGUST 27.

The following Papers and Report were read:—

1. *The Bearing of Pre-Cambrian Geology on Uniformitarianism.* *By* Dr. A. P. Coleman.

Pre-Cambrian rocks cover an enormous area in Canada and furnish probably as complete a series as any part of the world. Except for the lack of

fossils and a more or less considerable amount of metamorphism, they scarcely differ in character from later formations. They include great thicknesses of conglomerate arkose, quartzite and slate, evidently laid down by water; and the Lower Huronian basal conglomerate has all the features of boulder clay formed by a great ice-sheet. The extensive development of limestone and carbonaceous slate suggests life. The eruptive rocks found with the Keewatin and Huronian sediments are mainly of surface volcanic origin, lava streams and ash rocks.

If the oldest known rocks are of the character just stated, the evidence for uniformity in the world's history is very strong. There is no geological proof that the earth was hotter in the earliest times than at present; so that the common form of the Nebular Hypothesis receives no support from geology.

---

2. *The Pre-Cambrian Rocks of Canada. By* Professor W. G. Muller.

At the Toronto meeting in 1897, Dr. George M. Dawson, in his Presidential Address to Section C, summarised the knowledge of the Canadian pre-Cambrian. Since that time considerable progress has been made in deciphering the history of these ancient rocks. In 1904 an international committee, consisting of representatives of the United States and Canadian Geological Surveys, visited typical areas on both sides of the international boundary in the Lake Superior region. In 1906 a similar committee visited south-eastern Ontario and the Adirondack district in the New York State. The result of the work of both committees is that the same system of age classification is followed in both countries. The most ancient pre-Cambrian rocks, which consist of various volcanic types, greenstone now being the most characteristic, is known as the Keewatin. This volcanic series is cut through by granite and gneiss, to which the name Laurentian is applied. The Keewatin-Laurentian complex represents in Canada the Lewisian of Britain. After the intrusion of the Laurentian into the Keewatin, both were subjected to long-continued erosion, giving rise to conglomerates, greywackes, quartzites, arkoses, &c., now classed as Huronian. Three divisions, separated by unconformities, are recognised in the Huronian (Lower, Middle, and Upper or Animikie). The Huronian and Keweenawan may be said to correspond to the Torridonian of Scotland.

A series of conglomerates, sandstones, and marls, cut by great sills of trap, overlie the Huronian in the Lake Superior region. This series is known as the Keweenawan, and was classed as pre-Cambrian by the International Committee, although some workers in the field are inclined to group it with the Cambrian.

The following table shows the age classification of these rocks in descending order now recognised in Central Canada:—

	Keweenawan.
	(Unconformity.)
Huronian.	Upper or Animikie.
	Middle.
	Lower.
	(Great unconformity.)
	Laurentian.
	(Intrusive contact.)
	Keewatin.

The International Committee of 1906 decided, as did earlier workers, that the Grenville and Hastings series are one and the same, and that the term Hastings should be dropped.[1]

Other workers in the field hold different views, and believe that the

[1] *Journal of Geology*, Chicago, May 1907.

Grenville limestones represent chemical precipitates from the Keewatin ocean, and that these rocks should be placed below the great unconformity which separates the Huronian from the Keewatin-Laurentian complex. They place the Hastings series of Eastern Ontario with the Huronian of Western Ontario.[1]

The pre-Cambrian is being proved to be of more economic importance than it was formerly supposed to be. The great Sudbury and Cobalt ore deposits are found in these rocks, and promising indications of minerals of economic value are found widely extended over the area occupied by these rocks, which underlie at least one-half of the 3,750,000 square miles embraced in Canadian territory.[2]

---

3. *Report on the Erratic Blocks of the British Isles.*

See Reports, p. 169.

---

4. *An Outline of the Glacial Geology of Britain, illustrative of the Work of the Committee on Erratic Blocks. By* A. R. Dwerryhouse, *D.Sc.*

---

5. *The Glacial Phenomena of South Wales. By* Aubrey Strahan, *Sc.D., F.R.S.*

South Wales includes part of the southern margin of the glaciation of the British Isles. In the eastern part of the coalfield the drift has been transported southwards, nearly, but not quite, to the shore of the Bristol Channel. It contains great quantities of Old Red boulders from Brecknock, and it crossed the escarpments of lower Carboniferous rocks principally by way of the larger valleys. In the more central part of the coalfield the valleys trend south-westwards, and here also formed the channels by which Brecknock drift crossed the Carboniferous tract. The ice-sheet, however, was of sufficient magnitude to override all but the highest hills, to ignore sinuosities in the valleys, and to overflow from one valley into another. A part of the Pennant scarp, where it rises to a height of 2,000 feet, formed locally an insuperable obstacle, but the distribution of boulders, and the striæ prove that the Brecknock ice swept round it and reunited to the south of it. The drift of the central region rests upon a preglacial raised beach lying at about 15 to 20 feet above the present beach, and containing many shells of recent species. The western part of South Wales was occupied by ice which moved from north-west to south-east, and brought boulders from Pembrokeshire some miles up the Bristol Channel. This drift, which alone moved from sea landwards, is the only South Wales glacial deposit which contains shell-fragments among its boulders. It may be generally inferred that the continental shelf of which the British Isles form part should be considered in connection with the movements of the ice-sheets rather than the configuration of the land. That the shallow Irish Sea must have been occupied by ice is clear, not only near South Wales, but off the coast of North Wales. Too much importance also might easily be attributed to the Brecknock hills as a source of glaciation. Their effect, like that of the Pennant scarp referred to, may have been local.

---

[1] *Geol. Soc. Am.*, 1907, and 17th Report, *Bureau of Mines*, Ontario.
[2] *Journal Can. Mining Institute*, 1909.

6. *Preliminary Note on the Classification of the Permian of the North-East of England.* By DAVID WOOLACOTT, *D.Sc.*, *F.G.S.*

Sedgwick, Howse, and King classified the Permian according to the nature of its stratification or of the structures occurring in it; but as the bedding of the different divisions is often alike, and as the structures—whether concretionary, brecciated, pseudo-brecciated, or cellular—are not confined to particular horizons, divisions named on this basis are misleading and unsatisfactory. The use of the term 'fossiliferous' to mark off a division is also inadmissible. In the following classification the limestone is typically developed at the place the name of which is used to designate a group of strata. The divisions in descending order are:—

Middlesbrough Red Beds with Salt.—Red marls, marly sandstones and lenticular beds of salt, anhydrite and gypsum with fœtid fossiliferous magnesian limestones. 300 feet.

Roker Limestone.—Yellow limestone, regularly bedded; some beds compact, others formed of minute hollow spheres. 100 feet.

Fulwell Rocks.—Bedded yellowish and brownish concretionary (of various types) and non-concretionary limestones, in places highly fractured and brecciated; cemented crush-breccia occurs locally. Base often much disturbed by beds from below being forced into it, and by falling of lower layers into fissures and gashes. Irregular beds of amorphous marl are associated with these beds. Two fossiliferous horizons occur; one of fish remains at Fulwell, and the other of invertebrata at Byers Quarry. 150 to 200 feet.

Marsden Rocks.—Bedded yellow and brown limestones, slightly concretionary in places. Irregular masses of white limestone resembling Mountain Limestone occur. Brecciated beds (cemented crush-breccias) occur at different horizons: in places highly folded and fractured, but sometimes little disturbed. Breccia-fissures and breccia-gashes are found principally in this division. It is sometimes 'cellular,' due to solution of fragments out of cementing material of brecciated beds. This horizon has been a zone of thrusting, the amount of brecciation being determined by the relative compressive strength and rigidity of the strata. A flexible limestone occurs near the top of this division. 150 to 200 feet.

Claxheugh Limestone.—Yellow, earthy, friable, and crystalline limestone. Generally unbedded, in places very fossiliferous, sometimes brecciated (crush-breccia) and highly fractured. Its upper surface is very irregular. Some of the brecciated beds between Frenchman's Bay and Marsden, on Tynemouth Cliff, and at Blackhall Rocks are included in this division. Outcrops roughly parallel to coast as a continuous band. Brachiopods and most of the other genera of Permian fossils stop at this horizon in Durham. 50 feet.

Houghton Limestone.—Regularly bedded, thinly at base, more coarsely above. Top layers often highly displaced and tilted up; in one or two places it is entirely thrust out of position. Thickens greatly from north to south of county, and width of outcrop increases. Often full of geodes, 10 to 400 feet.

(The greatest thickness of magnesian limestone obtained by boring is about 800 feet.)

Marl Slate.—Greyish, yellowish-brownish, and blackish arenaceous and argillaceous laminated limestone. Numerous fish remains. Three or four feet thick.

Thin band of calcareous clay a few inches thick.

Yellow Sands.—An incoherent sandstone generally yellow along outcrop, occasionally variegated (iron oxides and manganese dioxide). In pit sections often greyish or bluish. Very variable in thickness. Top originally regular, but floor on which it rests irregular. Generally false-bedded,

although in places, especially near the top, it is regularly bedded. Grains rounded. 0 to 150 feet.

7. *New Faunal Horizons in the Bristol Coal-field.* *By* Herbert Bolton, *F.R.S.E., F.G.S.*

The well-known rarity of animal remains in the Bristol coal-field is proving to be due rather to the concealment of the measures beneath newer rocks than to any actual absence of fossils.

In 1906-7 the writer determined the existence of four horizons each possessing a marine fauna, between the top of the Millstone Grit and the lowest workable seam in the Ashton district; and further work upon the beds lying above the Bedminster seam at South Liberty Colliery, Bedminster, and at Coalpit Heath in the north of the basin, has proved the occurrence of others.

A section at South Liberty Colliery is as follows:—

	Feet.
Strata	127·4
Black Shale with *Anthracomya*	4·11
Strata	337·8
Grey Shale with *Anthracomya*	3·7
Strata	2·0
Dark grey Shale with shells	2 8
Strata	150·0
Black shell-bearing Shale	3·6
Strata	134·4
Bedminster Seam	3·0

At Coalpit Heath, a black shale forming the roof of the High Vein (Hollybush Vein of Parkfield) has proved exceptionally rich in specimens of *Leaia Leidyi var. Salteriana*, whilst *Estheria cf. tenella*, and *Anthracomya Phillipsi* also occur.

8. *Description of the Avon Section, Bristol, in illustration of Dr. A. Vaughan's Work on the English Carboniferous Limestone.* *By* Professor S. H. Reynolds, *M.A.*

9, *Lithology of the Carboniferous Limestone of Burrington Coombe, Somerset.* *By* Professor S. H. Reynolds, *M.A.*

10. *Unconformities on Limestone and their Contemporaneous Pipes and Swallow-holes.* *By* E. E. L. Dixon, *B.Sc., F.G.S.*

Calcareous rocks differ from other commonly occurring types in being appreciably soluble in atmospheric waters, and, in consequence, being eroded along underground channels where situated above saturation-level. Thus it is that one of their most striking physiographic characteristics is the occurrence in them of numerous caves and swallow-holes, of all sizes and shapes, often containing either debris of overlying rocks or deposits formed in them *in situ*. It is the purpose of this note to draw attention to the way in which this characteristic is reflected in the nature of certain unconformable junctions of limestones with younger rocks.

Unconformities may be divided, for our purpose, into two groups. In the first the underlying rocks have an approximately plane upper surface, the plane of the unconformity, and have evidently been base-levelled, by

either marine denudation or peneplanisation, before the deposition of the upper set upon them. With this group any limestones which occur below the unconformity appear to be devoid of pipes or swallow-holes contemporaneous in origin with the plane of the unconformity. Example: the junction of the Carboniferous Limestone with Triassic or Jurassic formations at most places, such as Upper Vobster, in the Bristol district, already described by many authors.

In the second group the rocks below the unconformity have not been maturely eroded before the deposition of those above, and the junction may in consequence be very uneven. Where the underlying rock is limestone the unevenness becomes most marked, for there the junction is complicated by pipes and swallow-holes contemporaneous with the unconformity and filled with material similar to that of the overlying formation, which has been deposited in them *in situ*. An example in which the unconformity, and consequently the piping, has been but slight is afforded by the junction of the upper and lower subzones of the *Syringothyris*-zone of the Carboniferous Limestone—*i.e.* by the mid-Avonian unconformity—at West Williamston, in Pembrokeshire.[1] There the basement-bed of the upper subzone fills pipes, up to 8 feet deep, in the upper part of the Caninia-oolite (the top of the lower subzone) below, the evidently undisturbed state of both the in-filling and the rest of the basement-bed above showing that the pipes have been formed before the deposition of the upper subzone. At a short distance from West Williamston the pipes in the oolite disappear as we approach the area characterised by continuous deposition of the Avonian; but at Pendine,[2] in the opposite direction, where the unconformity in the middle of this formation is greater than at West Williamston, the piping has extended for a greater depth into the limestones below.

A still more advanced stage of solution-erosion is shown by the Carboniferous Limestone at Ifton, in Monmouthshire, near Severn Tunnel Junction. The unconformity in this case occurs between the Carboniferous Limestone and the Millstone Grit; in the former have been eroded large steep-sided cavities, comparable only with swallow-holes, as well as small pipes resembling those at West Williamston, and both swallow-holes and pipes have been filled with an original deposit of Millstone Grit. This occurrence is the more interesting because the Carboniferous Limestone and the Millstone Grit have subsequently been covered up with Trias, but the junctions of both with the latter form an even surface, evidently a base-levelled plane, below which there are no contemporaneous—*i.e.* Triassic—pipes in the limestone.

Finally, an extreme case of solution-erosion preceding unconformable deposition on limestone is afforded by huge breccia-filled cavities in the Carboniferous Limestone of Pembrokeshire.[3] These cavities often extend from top to bottom of cliffs ranging up to more than 100 feet in height, and in some cases continue horizontally for over 100 yards. They are almost completely filled with blocks of limestone, of all sizes up to masses weighing hundreds of tons, which have fallen from the roof and sides, but also contain a little interstitial Triassic material *in situ*. The formation of the cavities, therefore, preceded the deposition of the Trias, and took place during the long period represented by the great unconformity between the latter and Carboniferous rocks. In this district, most, if not all, of the succeeding younger formation (the Trias), deposited on the upper surface of the limestone, has been removed, but there is evidence that that surface was a base-levelled plane. This belief, however, does not invalidate the conclusion that

[1] 'Summary of Progress' for 1906 (*Mem. Geol. Surv.*), 1907, p. 55.

[2] 'Summary of Progress' for 1902 (p. 43), 1904 (p. 44), and 1905 (p. 55); and 'The Country around Carmarthen' (in the press), *Mem. Geol. Surv.*

[3] 'Summary of Progress' for 1904 (*Mem. Geol. Surv.*), 1905, pp. 46-47.

such planes are devoid of contemporaneous swallow-holes, because the plane which is believed to have existed in this case must have truncated some of the breccia-filled cavities, and therefore have been of later origin.

MONDAY, AUGUST 30.

The following Papers and Reports were read:—

1. *Gold and Silver Ores of Canada. By* Professor W. G. MILLER.

It is only during recent years that mining in Canada has become important. In the central part of the Dominion the people had been educated in the belief that the country was essentially agricultural, and the mining industry was neglected. The successful development of Sudbury and the discovery at the end of 1903 of the far-famed Cobalt had created changed conditions, and mining was now getting its fair share of attention. The Province of Ontario has two mining schools, and liberal appropriations are annually made by the Legislature for geological and other work done to advance the mining industry.

Half of Canada is underlain by the most ancient of rocks, the Pre-Cambrian. The small point of these rocks that extends into the United States had made that country the world's leader in the iron industry. In this formation were also found the immense copper deposits of Michigan. On the northern side of the boundary line, Cobalt and Sudbury are in the Pre-Cambrian series, and it is not too much to expect that when Canada's hinterland is prospected numerous Sudburys and Cobalts will be found.

Sudbury to-day is turning out over half the world's supply of nickel and cobalt, about a sixth of the world's output of silver, besides producing in cobalt a metal which resembles nickel in many respects. Quebec produces over 80 per cent. of the world's asbestos, and corundum is found in larger quantities in Canada than elsewhere.

Gold has been found in large quantities in British Columbia and the Yukon. In the height of the Yukon's prosperity, Canada stood third among the world's producers of gold. Lode mining for gold has become a well-established industry in British Columbia. The gold of the province is found in smelting ores mixed with copper pyrites and pyrrhotite, and also in essentially free melting ores.

In the region lying between the western boundary of Ontario and the eastern boundary of British Columbia the production of gold has been small, and has been found in placers; but discoveries of gold have recently been made in the district tributary to Prince Albert. In Ontario there is gold found in Hastings county and Temagami associated with arsenic, and in other places it is found in quartz or associated with iron pyrites. In Northern Quebec it is found in deposits smaller than those of Ontario, while in the southern part of Quebec it has been worked in placers. In Nova Scotia rich free milling ores are found in narrow veins.

British Columbia and Ontario are the silver-producing provinces. The Cobalt region has yielded very rich veins of silver, and adjoining districts are opening out valuable workings. Little prospecting has been done as yet in the territory between Cobalt and Port Arthur.

---

2. *Copper and Nickel Deposits of Canada.* By Dr. A. P. COLEMAN.

Copper is widely found in Canada, especially in Southern British Columbia and in Ontario. In the latter province the copper now mined

is associated with nickel. The nickel mines of Ontario, which produce more than half the nickel of the world, are all connected with a great eruption sheet a mile and a quarter thick, thirty-seven miles long, and seventeen miles wide. The deposits all occur at the margin of the sheet in depressions beneath it or in offset deposits pushing out into the country rock.

The nickel eruption, norite on the lower side, merging into micropegmatite on the upper side, is really a laccolithic sill bent into a synclinal shape by the collapse of the Archæan rocks beneath when the molten matter ascended to its present position.

---

3. *Iron Deposits of Canada. By* Professor W. G. Miller.

Canada's iron industry is not yet a large one, but it is making satisfactory progress. One centre of the iron-smelting industry is at Sydney, B.C., but there are smelting industries in a number of other places. The chief productive iron ranges of Ontario are at Michipicoten, at Moose Mountain near Sudbury, and at Bessemer in Eastern Ontario. The Lake Superior mines have made the United States the leaders in this industry, but similar iron ranges are found in Canada from the Lake Superior region eastwards to Ungava, and westward to the Great Slave Lake, although these have been little explored. As the country is opened up, Canada is certain to have an important iron industry.

---

4. *Placer Gold Mining in Canada. By* J. B. Tyrrell, *M.A.*

Placer mining in America may be said to have had its origin in California in 1848. After having engaged in mining for a few years, many of the thrifty and successful miners settled down in their adopted State and lent their time and fortunes to its development. But Canada profited most from those who were less successful, for many of the disappointed California prospectors wandered to British Columbia, where they discovered the gold-bearing gravels of White Horse Creek in East Kootenay, and of Williams and other Creeks in Cariboo, from which gold to the value of £14,000,000 was extracted.

The Cariboo diggings, after being abandoned by the individual miners, were taken over by mining companies that attempted to work them by hydraulic processes. But the supply of water was insufficient. Large reservoirs were built one after the other, and these proved to be simply evaporating basins, so that as the areas of the reservoirs were increased, the quantity of available water diminished.

Other prospectors crossed the Rocky Mountains into Alberta and discovered fine gold in the sands of the Saskatchewan and Peace Rivers. As these streams derive their supplies of gold from the soft and slightly auriferous Laramie (Eocene) sandstones which form their banks, they may be regarded as permanent sources of a small annual supply of that metal.

But the great region between the Rocky Mountains on the east and the Cascade Mountains on the west appealed most strongly to the prospectors, so they kept moving north-westward, first discovering the Cassiar country, and finally, in 1896, the Klondike, from which latter camp gold to the value of about £25,000,000 has been extracted. The richest pockets in this region have now been exhausted, and the individual miners have mostly been replaced by companies that have begun to extract the remaining gold from the lower grade gravels with dredges and hydraulic plants. It is to be hoped that these companies will succeed better than those that attempted to operate in the Cariboo country.

The Klondike lies in an unglaciated area, and the richness of its gold-bearing gravels is due to long-continued erosion and concentration of Pre-Cambrian schists carrying small stringers of auriferous quartz rather than to the exceptional richness of any lodes from which these gravels were derived.

In Eastern Canada placer deposits were worked for a short time in the valley of the Chaudiere River, in the Province of Quebec, but as a general rule rich placers are not to be expected in that country, for it has been severely glaciated, and any gravel deposits which may be present in it have been almost entirely formed from the reassorting of boulder-clays by water, while gravels derived exclusively from the wearing down of restricted areas of auriferous rocks are conspicuously absent.

---

5. *The Rare Metals of Canada.* *By* Professor T. L. Walker, *Ph.D.*

---

6. *Exhibition of the Material described as Geyserite from the Mount Morgan Mine, Queensland.* *By* Professor J. W. Gregory, *F.R.S.*

---

7. *Topographical and Geological Terms in Local Use in South Africa.* *By* Charles F. Juritz, *M.A.*, *D.Sc.*, *F.I.C.*

On pages 291–296 of the 1908 Report of the British Association for the Advancement of Science appears a glossary of geological and topographical terms commonly employed in South Africa, inserted as the Report of a Special Committee appointed to determine the precise significance of such terms. As the list contains a few errors it may perhaps be permitted me to draw attention to these, seeing that it is obviously desirable that a glossary of this nature should possess the merit of perfect reliability.

'Bosch' (p. 291) means 'a wood,' but it does not mean 'a bush,' except where the latter term is used as a synonym for 'wood.' The proper translation for 'bush' is 'bos.' Thus the rhinoceros bush, as it is called (*Elytropappus rhinocerotis*) goes by the name of 'rhenoster bos,' but 'Assegai Bosch' would denote a forest composed of what are in Cape Colony known as 'Assegai trees' (*Curtisia faginea*).

In the last line of p. 291 'Blaauw' (meaning 'blue') is incorrect: it should be spelt 'Blauw.'

The plural of 'duin' (p. 292) is 'duinen,' not 'duien.' 'Castle' in Dutch is 'Kasteel,' not 'Kastrel,' as printed on p. 292 (last line).

The word 'Gouph' I have invariably heard pronounced 'Cope'—never 'Coop.'

I am glad to see that the very common error 'Krantz' is pilloried; but the correction itself is incorrect, inasmuch as 'Kranz' is put forward instead as good orthography.

'Naauwte,' like 'Blaauw,' should have only one 'a.'

With regard to 'plaat' (p. 294), I must express my belief that the etymology there given is quite erroneous. The correct spelling of the word used by way of illustration is, to the best of my knowledge, 'Klipplaats,' which means literally 'Stone Place.' There is no granite within hundreds of miles of the locality called by that name; the reference is obviously to a part of the country where many pebbles lie loosely scattered about.

'Portje' should be spelt 'Poortje.'

'Sluit' deserves the pillory quite as much as 'Krantz.' It is a most egregious misapplication. The word spelt as above is a verb, and means 'to lock.' What is intended is 'sloot,' *i.e.*, 'a ditch.'

'Spitz kop' is an error of similar type to 'Krantz,' and owes its origin to the persistent habit of Germanising Dutch words, which is curiously common amongst visitors to South Africa from England.

In illustration of the word 'Veld' (a term, by the way, often half Germanised, into a hybrid 'veldt'), the expression 'Boschveld' is given, with the meaning 'bush country' appended. 'Boschveld' may be construed into forest country —although even then it would contain a contradiction—as a 'veld' cannot be a forest—but it is certainly not bush country, which could only be correctly rendered 'Bosveld.'

It follows from what has already been said that 'Kimberlite' is not 'Blaauwgrond' but 'Blauwgrond.'

'Bosjesman's klip' is also misspelt, and so is 'Harde Bank,' in both cases an 'i' being substituted for an 'e.'

Lastly, 'Ijzer klip,' when written by a Dutchman, usually wears the form 'IJzer klip'—note the double capital. In English it should be spelt 'Yzer klip,' 'IJ' being simply the Dutch form of the English letter 'Y.' It bears some analogy to the 'VV' which we often see in the older printed books instead of 'W.' When translating a Dutch word containing 'IJ' into English characters we should no more retain the Dutch form than we would, for example, in the case of the Greek 'P,' otherwise we should, for the sake of consistency, adopt such a spelling as '*P*hododendron.'

The laxity prevalent in South Africa as regards the spelling of local names and topographical terms generally is most remarkable, and the cacography tends to become perpetuated and stereotyped when writ large—as it often is—on railway station signboards, *e.g.*, at NAAUWPOORT or at BLAAUWKRANTZ (*sic*), or when printed across what are ostensibly authoritative and standard maps of the country. The efforts which are being put forth by the British Association to check this looseness are therefore to be welcomed.

---

8. *Report on Topographical and Geological Terms used locally in South Africa.*—See Reports, p. 149.

---

9. *Report on the Faunal Succession in the Lower Carboniferous Limestone (Avonian) of the British Isles.*—See Reports, p. 187.

TUESDAY, AUGUST 31.

The following Papers and Reports were read:—

1. *The Volcano of Matavanu. By* Dr. TEMPEST ANDERSON.

The Volcano of Matavanu, in Savaii, an island of the Samoan group, was formed in 1905. It is of the efflussive type, *i.e.*, characterised by the outflow of large quantities of lava with comparatively little explosion or discharge of ashes, lapilli, or pumice. The crater contains a quantity of molten lava in constant agitation, breaking in waves on the walls, and throwing up fountains of liquid basalt. The lava is in rapid motion, and enters a tunnel in one end of the crater, by which it flows under the already solidified lava field a distance of several miles to the sea, into which it falls with violent explosions. The lavas throughout have been very fluid, and have covered a large tract of country. The paper included a discussion of the many resemblances and few differences between the phenomena of Matavanu and Kilauea in Hawaii.

---

2. *On Remains of a Megalosaurian Dinosaur from New South Wales. By* A. SMITH WOODWARD, *F.R.S.*

A tooth and a posterior caudal vertebra of a small Megalosaurian, characteristic in all respects, have lately been received by the British

Museum from the Upper Cretaceous opal-bearing sandstone of Lightning Ridge, near Walgett, New South Wales. The specimens are opalised, and were found associated with other bones and shells in a similar condition. Evidence of Dinosaurs has already been described from the supposed Trias of Queensland and from the Jurassic of Victoria, but the new fossils are the first traces of an Australian Dinosaur of Cretaceous age.

---

3. *On a Tooth of a Triassic Dinosaur from San Paulo, Brazil.* *By* A. Smith Woodward, *F.R.S.*

Dr. Rudolph von Ihering submitted to the author a small tooth which he discovered in a red rock at San José do Rio Preto, in the west of the State of San Paulo, 450 kilom. from the capital. The specimen is solid, laterally compressed, with smooth tumid faces and sharp serrated edges. It lacks the basal part, but as preserved it measures 1 cm. in maximum width by 2 cm. in height. The serrations are uniform in size, relatively large, and peculiar in being inclined a little upwards, not at right angles to the edge. The tooth thus resembles that of the Thecodontosaurian Dinosaurs, which are characteristic of the Trias and Rhœtic formations of other parts of the world.

---

4. *Certain Aspects of British Scenery, as illustrating the Work of the Geological Photographs Committee. By* Professor S. H. Reynolds, *M.A.*

---

5. *Seventh Report on the Fauna and Flora of the Trias of the British Isles.*—See Reports, p. 150.

---

6. *Report on the Igneous and Associated Rocks of the Glensaul and Lough Nafooey Areas, Co. Galway.*—See Reports, p. 163.

---

7. *Report on the Excavation of Critical Sections in the Palaeozoic Rocks of Wales and the West of England.*—See Reports, p. 181.

---

8. *Interim Report on the Correlation and Age of South African Strata, etc.*

---

9. *Report on the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, etc.*—See Reports, p. 177.

---

10. *Fourth Report on the Crystalline Rocks of Anglesey.* See Reports, p. 164.

---

11. *Interim Report on the Microscopical and Chemical Composition of Charnwood Rocks.*

---

12. *Interim Report on the Ancient Salt Lakes at Biskra, Algeria.*

Section D.—ZOOLOGY.

President of the Section.—A. E. Shipley, M.A., D.Sc., F.R.S.

THURSDAY, AUGUST 26.

The following Papers were read:—

1. *On the Origin of the Vertebrates. By* E. S. Goodrich, *F.R.S.*

The object of this paper was to show that none of the theories of the Origin of the Vertebrates hitherto brought forward, and deriving them from some existing class of the Invertebrata, is satisfactory; because these theories violate the sound principles of phylogeny based on the combined evidence of comparative anatomy and physiology, embryology, and palæontology. This evidence enables us to trace back the Gnathostomes to a primitive shark-like fish; the Gnathostomes and Cyclostomes to a common form of much more uniformly segmented structure; and finally the Craniata and Cephalochorda to an ancestor of very simple structure, without dermal skeleton and without pronounced cephalisation, which probably became extinct even before the Silurian age.

---

2. *On the Subcutaneous Fat Bodies in Bufo. By* C. L. Boulenger.

FRIDAY, AUGUST 27.

The President delivered the following Address:—

I.

Charles Darwin.

This is the year of centenaries. Perhaps in no other year in history were so many men born destined to impress their genius on the literature, the politics, and the science of the world as in 1809. The number of literary men who first saw the light in that *annus mirabilis* is almost too long to mention—Mark Lemon, the genial editor and one of the founders of *Punch*; 'Crimean' Kinglake; John Stuart Blackie, till lately a well-known figure in Edinburgh; Monckton Milnes, the first Lord Houghton, 'poet, critic, legislator, the friend of authors' and the father of Lord Crewe who at present presides over that most important of all Government

offices—that of the Colonies. One could prolong the list, and one must at least mention the names of Louis Braille, the inventor of the Braille type for the blind, of Fanny Kemble and of Elizabeth Barrett Browning, before passing on to remind you that this year is also the centenary of Tennyson who, with Browning, formed the twin stars of poetry during the reign of Queen Victoria, and who from his intimate knowledge of natural history and his keen power of observation was essentially the poet of Darwinism. Of his long-life friend, born the same year, Edward Fitzgerald, the translator—one feels almost inclined to say author—of Omar Khayyám, and of the gifted musician Mendelssohn there is no time to speak.

On this side of the Atlantic, and yet not wholly on this side, for he spent five impressionable school years at Stoke Newington, we have that 'fantastic and romantic' genius Edgar Allan Poe.[1] Later he studied at West Point, where surely he must have been as incongruous a student as James Whistler himself. We have also that kindly, humorous physician Oliver Wendell Holmes, a nature 'sloping towards the southern side' as Lowell has it. Amongst many recollections of literary men I cherish none more dearly than that I once entertained him in my Cambridge and once visited him in his.

Three other names stand out. William Ewart Gladstone, that leader of men, a politician and a statesman capable more than most men at once of arousing the warmest affection of his followers and the bitterest hatred of those who went the other way. Cultured as he was and widely read, he had his limitations, and although his tenacious memory was stored with the humanities of all the ages, he was singularly devoid of any knowledge of science. If we may paraphrase the words of Lord Morley in his estimate of Gladstone's writings, we would say that his place is not in science, 'nor in critical history, but elsewhere.'

Abraham Lincoln, the greatest man born on this continent since the War of Independence, was some ten months older than Gladstone. Both men were great statesmen, both men were liberators; for we must not forget that in many minds the help Gladstone gave to Italy in her struggle for freedom and union remains the most enduring thing he achieved.

Yet in externals how different! One the finished, cultured product of the most aristocratic of our public schools and the most ancient of our universities, the other little read in the classics or in mediæval and ecclesiastical lore, yet deeply versed in the knowledge of men and how to sway them. Rugged, a little rough if you like, humorous and yet sad, eminently capable, a strong man, and at heart 'a very perfect gentleman.'

On the same day, February 12th, upon which Lincoln first saw the light, was born at the 'Mount,' Shrewsbury, a little child destined as he grew up to alter our conceptions of organic life perhaps more profoundly than any other man has ever altered them, and this not only in the subjects he made his own, but in every department of human knowledge and thought.

Being as I am a member of Charles Darwin's own college, coming as I do straight from the celebration in which the whole world united to do his memory honour, it would seem meet that I should in this year of the centenary of his birth devote this address to a consideration of his life and of his work, and of such confirmation and modification of his theories as the work of the last fifty years has revealed.

As to the man, I can but quote two estimates of his character, one by a college companion who lived on terms of close intimacy with Darwin

[1] Poe lived from his eighth to his thirteenth year at the 'Manor House School,' Stoke Newington, at that time a village, now swallowed up by the metropolis. Poe described the place as he knew it, and his schoolmaster, Dr. Bransby, in *William Wilson.*

when at Christ's, the other the considered judgment of one who knew and loved and fought for Darwin in later life.

Mr. Herbert says:—

'It would be idle for me to speak of his vast intellectual powers . . . but I cannot end this cursory and rambling sketch without testifying, and I doubt not all his surviving college friends would concur with me, that he was the most genial, warm-hearted, generous, and affectionate of friends; that his sympathies were with all that was good and true; and that he had a cordial hatred for everything false, or vile, or cruel, or mean, or dishonourable. He was not only great, but pre-eminently good, and just, and lovable.'

Professor Huxley, speaking of his name, says:—

'They think of him who bore it as a rare combination of genius, industry, and unswerving veracity, who earned his place among the most famous men of the age by sheer native power, in the teeth of a gale of popular prejudice, and uncheered by a sign of favour or appreciation from the official fountains of honour; as one who, in spite of an acute sensitiveness to praise and blame, and notwithstanding provocations which might have excused any outbreak, kept himself clear of all envy, hatred, malice, nor dealt otherwise than fairly and justly with the unfairness and injustice which was showered upon him; while, to the end of his days, he was ready to listen with patience and respect to the most insignificant of reasonable objectors.' [1]

It has been somewhat shallowly said—said, in fact, on the day of the centenary of Darwin's birth—that 'we are upon very unsafe ground when we speculate upon the manner in which organic evolution has proceeded without knowing in the least what was the variable organic basis from which the whole process started.' Such statements show a certain misconception, not confined to the layman, as to the scope and limitations of scientific theories in general, and to the theory of organic evolution in particular. The idea that it is fruitless to speculate about the evolution of species without determining the origin of life is based on an erroneous conception of the true nature of scientific thought and of the methods of scientific procedure. For science the world of natural phenomena is a complex of procedure going on in time, and the sole function of natural science is to construct systematic schemes forming conceptual descriptions of actually observed processes. Of ultimate origins natural science has no knowledge and can give no account. The question whether living matter is continuous or not with what we call non-living matter is certainly one to which an attempted answer falls within the scope of scientific method. If, however, the final answer should be in the affirmative, we should then know that all matter is living; but we should be no nearer to the attainment of a notion of the origin of life. No body of scientific doctrine succeeds in describing in terms of laws of succession more than some limited set of stages of a natural process; the whole process—if, indeed, it can be regarded as a whole—must for ever be beyond the reach of scientific grasp. The earliest stage to which science has succeeded in tracing back any part of a sequence of phenomena constitutes a new problem for science, and that without end. There is always an earlier stage and to an earliest we can never attain. The questions of origins concern the theologian, the metaphysician, perhaps the poet. The fact that Darwin did not concern himself with questions as to the origin of life nor with the apparent

[1] *Life and Letters of Charles Darwin*, vol. ii. 1887, p. 179.

discontinuity between living and non-living matter in no way diminishes the value of his work. The broad philosophic mind of the great master of inductive method saw too fully the nature of the task he had set before him to hamper himself with irrelevant views as to origins.

No well instructed person imagines that Darwin spoke either the first or the last word about organic evolution. His ideas as to the precise mode of evolution may be, and are being, modified as time goes on. This is the fate of all scientific theories; none are stationary, none are final. The development of science is a continuous process of evolution, like the world of phenomena itself. It has, however, some few landmarks which stand out exceptional and prominent. None of these is greater or will be more enduring in the history of thought than the one associated with the name of Charles Darwin.

I cannot, indeed, attempt to weigh or estimate the influence and the far-reaching import of the work which all the world has been weighing and estimating during this year, the centenary of his birth and the jubilee of the *Origin of Species*. I cannot, to my intense regret, give you any personal recollections of Darwin, for though I think I once saw him in the streets of Cambridge, I have to my sorrow never been absolutely sure that this was so.

But in reading his writings and his son's most admirable Life, one attains a very vivid impression of the man. One of his dominant characteristics was simplicity—simplicity and directness. In his style he was terse, but he managed to write so that even the most abstruse problems became clear to the public. The fascination of the story he had to tell was enhanced by the direct way he told it.

One more characteristic. Darwin's views excited at the time intense opposition and in many quarters intense hatred. They were criticised from every point of view, and seldom has a writer been more violently attacked and abused. Now what seemed to me so wonderful in Darwin was that—at any rate as far as we can know—he took both criticism and abuse with mild serenity. What he wanted to do was to find the truth, and he carefully considered any criticism, and if it helped him to his goal he thanked the critic and used his new facts. He never wasted time in replying to those who fulminated against him; he passed them by and went on with his search.

In the development of the theories associated with Darwin's work the New World played a prominent part. Darwin's 'Wanderjahre' were spent on this side of the Atlantic. The central doctrine of evolution through natural selection was forced upon his mind by the studies and researches he made in South America during the voyage of the *Beagle*. The numerous observations in all departments of natural science and the varied forms of life he came across in this classical journey were the bricks with which he built many of his later theories. The storm of controversy which the *Origin of Species* awoke was at least as violent in America as in Great Britain, and we must not forget the parts played by men like Hyatt, Fiske, Osborn, and many others, and above all by Asa Gray and by Brooks of Baltimore, whose recent death has robbed America of perhaps her greatest Darwinian.

It is a somewhat remarkable fact that whilst the works of Darwin stimulated an immense amount of research in biology, this research did not at first take the line he himself had traced. With some exception the leading zoological work of the end of the last century took the form of embryology, morphology, and palæontology, and such subjects as cell-lineage, 'Entwickelungsmechanik'; the minute structure of protoplasm, life-histories, teratology, have occupied the minds of those who interest themselves in the problems of life. Along all these lines of research man has been seeking for the solution of that secret of nature which at the

bottom of his heart he knows he will never find, and yet the pursuit of which is his one-abiding interest. Had Frank Balfour lived we should, I think, have sooner returned to the broader lines of research as practised by Darwin, for it was his intention to turn himself to the physiology—using the term in its widest sense—of the lower animals. Towards the end of the nineteenth century, stimulated by Galton, Weldon began those series of measurements and observations which have culminated in the establishment, under the guidance of his friend and fellow-worker, Karl Pearson, of a great school of eugenics and statistics in London. With the beginning of the twentieth century came the rediscovery of Mendel's facts, and with that an immediate and enormous outburst of enthusiasm and of work. Mendel has placed a new instrument in the hand of the breeder, an instrument which, when he has learnt to use it, will give him a power over all domesticated animals and cultivated crops undreamt of before. We are getting a new insight into the working of heredity and we are acquiring a new conception of the individual. The few years which have elapsed since men's attention was redirected to the principles first enunciated by the Abbot of Brünn have seen a great school of genetics arise at Cambridge under the stimulating energy of Bateson, and an immense amount of work has also been done in France, Holland, Austria, and especially in the United States. As the work has advanced, new ideas have arisen and earlier formed ones have had to be abandoned; this must be so with every advancing science; but it has now become clear that mutations occur and exist especially in cultivated species, and that they breed true seems now to be established. In wild species also they undoubtedly occur, but whether they are so common (in uncultivated species) remains to be seen. If they are not, in my opinion a most profitable line of research would be to endeavour to determine what factor exists in cultivation which stimulates mutation.

To what extent Darwin's writings would have been modified had Mendel's work come into his hands we can never know. He carefully considered the question of mutation, or, as they called it then, saltation, and as time went on he attached less and less importance to these variations as factors in the origin of species. Ray Lankester has recently reminded us that Darwin's disciple and expounder, Huxley, 'clung to a little heresy of his own as to the occurrence of evolution by saltatory variation,' and there must have been frequent and prolonged discussion on the point. That 'little heresy' has now become the orthodoxy of a number of eager and thoughtful workers who are at times rather aggressive in their attacks on the supporters of the old creed. 'That mutations occur and exist is obvious to everyone, but that they are of frequent occurrence under purely natural conditions is,' Sir William Thiselton-Dyer thinks, 'unsupported by evidence.' The delicate adjustment between an organism and its natural surroundings suggests that sudden change of a marked kind would lead to the extinction of the mutating individual. As far as I can understand the matter in dispute, Darwin and his followers held that evolution had proceeded by small steps, for which we may accept de Vries' term fluctuations; whilst the Mutationists hold that it has advanced by large ones, or mutations. But it is acknowledged that mutations are not all of the same magnitude, some, *e.g.*, albinism; brachydactyly in man; dwarf habit or glabrousness in plants may be large; others, *e.g.*, certain differences in shade of colour or in size, are insignificant, and indeed Punnett has suggested that under the head of fluctuating variation we are dealing with two distinct phenomena. He holds that 'some of the so-called fluctuations are in reality mutations, whilst others are due to environmental influence.' He thinks the evidence that these latter are transmitted is slender, and later states that 'Evolution takes place through the action of selection on these mutations. Where

there are no mutations there can be no evolution.' The disagreement about the way in which evolution has proceeded has perhaps arisen from a misunderstanding as to the nature of the two kinds of variation described respectively as mutations and fluctuations. Mutations are variations arising in the germ-cells and due to causes of which we are wholly ignorant; fluctuations are variations arising in the body or 'soma' owing to the action of external conditions. The former are undoubtedly inherited, the latter are very probably not. But since mutations (using the word in this sense) may be small and may *appear* similar in character to fluctuations, it is not always possible to separate the two things by inspection alone. The whole matter is well illustrated by the work of Johannsen on beans. He found that while the beans borne by any one plant vary largely in size, yet if a large and a small bean from the same plant are sown, the mean size and variability of the beans on the plants so produced will be the same. The differences in size are presumably due to differences of condition and are not inherited. But if two beans are sown, one from a plant with beans of large average size, and one from a bean of small average size, the bean plant whose parent had the high average will bear larger beans than the one from the parent with small average beans. The faculty of producing a high or low mean size is congenital, is a mutation in the sense used above, and is inherited. It is no doubt unfortunate that the word mutation has been used in several different senses, for it seems to have led to most regrettable confusion and misunderstanding.

As I have said, in such a year, and in my position, I ought perhaps to have devoted the whole of this address to the more philosophical side of our subject; but, in truth, I am no philosopher, and I can only say, as Mr. Oliver Edwards, 'an old fellow-collegian' of Dr. Johnson's said to the 'great lexicographer' when they met after nearly half a century of separation: 'I have tried too in my time to be a philosopher, but I don't know how, cheerfulness was always breaking in.'

II.

Organising Zoology.

I now turn to a subject of the greatest moment and of the greatest difficulty, and one on which there is little general consensus of opinion. The question I wish to raise is this—are the zoologists of the world setting about their task in an economic and efficient way?

We live surrounded by a disappearing fauna. Species are disappearing from the globe at a greater rate than even the most ardent mutationist claims they are appearing. To mention but a few striking cases: The European beaver has almost gone, though a few linger on around the periphery of the Continent. Norway, the lower Danube, Eastern and Arctic Russia still harbour them, and a very few are said still to inhabit the Rhine and the Rhone. The European bison is now represented by a few wild specimens in the Caucasus. The American bison is reduced, and that by the deliberate and calculated action of man, to a few herds most carefully preserved by Government; the largest of these, containing some 600 heads, is now at the National Park at Wainwright. Equally deliberate and equally calculated is the destruction of the fur-seal which threatens soon to be complete. The Greenland sealing is almost a thing of the past. In 1860 British vessels killed 68,278 seals; in 1866, 103,758; and this went on until 1895, when the pursuit was abandoned by the British, it being no longer found to pay them, though Norwegians still continue

'sealing.' In 1859 19 vessels sailing from British ports killed 148 whales; in 1881 12 vessels killed 48 whales; last year 6 Dundee vessels killed but 15, and the year before that but 3. The whalers sailing from Newfoundland ports killed 1,275 whales in 1904, 892 in 1905, and only 429 in 1906.

At the present time certain Norwegian whaling companies have been for the last few years actively at work in the Shetlands, and are killing off as fast as they can the common rorqual (*Balænoptera musculus L.*), the lesser rorqual (*B. rostrata*), Sibbald's rorqual (*B. sibbaldi* Gray), the cachalot (*Physeter macrocephalus* L.), the humped-back whale (*Megaptera boops* L.), and, when they can reach him, the Atlantic right whale (*Balæna mysticetus* L.). These are killed primarily for their blubber, but the economy of the factories rivals that of the Chicago pork packing industries. Nothing is wasted, the flesh is made into sausages, which are readily eaten in Central Europe, and the bones are ground up to make manure. No animal which produces but few young can withstand such persistent and organised attacks on the part of man, and I fear, before many years are passed, many species of whale will be extinct. At the present moment the two right whales seem almost on the verge of extinction, and *Balæna mysticetus* will probably go before *B. australis*. Nothing shows this more clearly than the price of whalebone, which has gone up in the last eighty-four years from 56*l.* per ton to 2,100*l.* per ton, or from 12cs. a pound to $4.90, and in some years to $5.80 a pound. The number of pounds on sale in the United States has dropped from 2,916,500 in 1851 to 96,600 in 1906. With the whales will disappear the whale-lice and the whole of the very interesting parasitic fauna which inhabit their vast interiors.

The disappearance of the large game from enormous tracts of country in Africa is too well known to delay us. The elephant, except where preserved in the Litzikama Forest, near Mossel Bay, and in the Addo Bush, near Port Elizabeth, is exterminated south of the Limpopo. The price of ivory again is a measure of the nearness of its extinction. The best pieces, which are used for billiard balls, have risen in price from 55*l.* a cwt. in 1882 to an average of 100*l.* a cwt. in 1908. The common and the brindled gnu (*Connochoetes taurinus*) are fated to follow the extinct quagga. The blesbok (*Damaliscus albifrons*), formerly found in thousands in Cape Colony, the Transvaal, and Bechuanaland, is now very rare and seems doomed. The giraffe has long been driven out from South Africa, though it still roams over large tracts of country in East and Central Africa.

Perhaps the most striking case of the disappearance of a mammalian fauna is that presented in Western Australia. Here many districts are now said to be entirely devoid of indigenous mammals, and this depletion is in the main an affair of only the last thirty years, and many of the local extinct forms are still remembered by the older natives and colonists. Mr. Shortridge, a collector who has worked for some years in South-west and Western Australia, writes in a letter: 'The entire disappearance of so many species over such large tracts of country is generally considered to be due to some epidemic perhaps brought into the land by introduced animals. It is to be noted that they have died out chiefly in the dry regions, where, except for the introduction of sheep, there has been very little alteration in the natural conditions. Rabbits, although already very numerous in the Centre and South-east, have not as yet found their way to the North-west.' Amongst the mammals which have almost, if not quite, disappeared from West Australia are the banded wallaby (*Lagostrophus fasciatus*), the hare wallaby (*Lagochestes hirsutus*), the rat-kangaroos (*Potorous gilberti* and *P. platyops*). The indigenous rats and mice of Australia are disappearing even faster than the marsupials, and it seems probable that many will not be heard of again.

A very few years ago the ship employed by the company which is exploiting the phosphates of Christmas Island introduced the brown rat (*M. decumanus*) there. Within a short time the two indigenous rats first collected by Mr. C. Andrews, of the British Museum, named *Mus macleari* and *Mus novitatis*, were wiped out of existence. The same animal having been introduced in North America, is gradually spreading, and as it spreads the native fauna of Muridae is slowly vanishing.

To adorn our ladies' heads some of the most beautiful of birds are being systematically exterminated. In the London market alone were sold last year some 50,000 sooty terns (*Sterna fuliginosa*, *S. anæstheta*, and *S. bonata*), 20,000 specimens of the crowned pigeon (*Goura*) from New Guinea, their sole habitat, immense numbers of 'osprey' feathers, egret and heron, and over 50,000 birds of paradise, or more than double the number of the year before.

I have no time to continue this melancholy record, but it could be prolonged almost indefinitely.

When we reflect how greatly we treasure every scrap of knowledge we can glean about such recently extinct animals as the *Rhytina*—Steller's sea-cow—the dodo, the great auk, we must see that if it be impossible to check the gradual disappearance of those animals doomed to extinction, we should at least monograph them and take every care that what can be permanently kept of their structure should be kept. In respect to the recording of the habits and physical features of a disappearing race, the anthropologists are setting an example which the zoologists would do well to follow.

We are living with a disappearing fauna around us, and numerous as the museums of the world are, and skilled and painstaking as the curators of these museums are, they are both wholly inadequate to deal with the material at hand. Some dozen years ago Dr. Günther made a very careful estimate of the number of species of animals which were known in the years 1830 and 1881. I summarise his table:—

Number of Species known in the years 1830 *and* 1881.

	1830.	1881.
Mammalia	1,200	2,300
Aves	3,600	11,000
Reptilia and Batrachia	543	3,400
Pisces	3,500	11,000
Mollusca	11,000	33,000
Bryozoa	(40)	120
Crustacea (year 1840)	(1,290)	7,500
Arachnida	1,408	8,070
Myriapoda	450	1,300
Insecta	49,100	220,150
Echinodermata (1838)	(230)	1,843
Vermes (1838)	(372)	6,070
Coelenterata (1834)	500	2,200
Porifera (1835)	(50) *say*	400
Protozoa (1838–44) *say*	(305) ,,	3,300
	73,588	311,653

Taking an average year between 1881 and the present date, but rather nearer the latter, because each year the number of newly described species becomes larger, Dr. Sharp tells me that according to the zoological record 12,449—let us call it 12,450—new species were described in the year 1897.

Number of new Species described in the year 1897.

Mammalia	285
Aves	105
Reptilia and Batrachia	140
Pisces	148
Mollusca	1,077
Brachiopoda	7
Bryozoa	6
Crustacea	239
Arachnida	659
Myriapoda	275
Insecta	8,364
Echinodermata	491
Vermes	294
Coelenterata	164
Porifera	95
Protozoa	100
	12,449

This number, however, includes fossils which I do not think were included by Dr. Günther. We might deduct 450 for them if we wish to confine our attention to living animals. This leaves us 12,000. If we multiply this by 27, the number of years which have elapsed since Dr. Günther made his estimate, we find a total of 324,000. This number is possibly too large, as it makes no allowance for synonyms, still it is a rough indication that since 1881 the number of described species has been doubled. Isolated groups, such as the mammals, treated in the same way, give us fairly similar results, so that now we may, I think, say that there are over 600,000 described species of living animals.

It thus appears that during the fifty-one years in the middle of the last century the number of known species grew by some 238,000, giving an average increase of a little under 5,000 per annum. At the present day there are far more workers in the field than there were thirty years ago, museums have multiplied, and there are many more zoologists, and it is now estimated that the number of species annually described and named amounts to some 12,000.

The number, large as it seems, is, however, but small in comparison with the number of species collected and deposited in museums where no one has time to work them out. It is still smaller in comparison with the vast numbers of species as yet uncaptured. Dr. Sharp, in 1895, calculated that there were a quarter of a million known and described insects. This was an increase of 30,000 over Günther's figures of fifteen years before, but he states that in his opinion this quarter of a million is but one-tenth of those which exist.

With the exception of the larger mammalia—though the Okapi warns us the exception may yet prove the rule—there is no group of animals which may not yield us new surprises—no group which we can regard as well worked out, though naturally some are better known than others. What, then, are the zoologists of the world doing to record the animal life around them? One thing of late is certainly an improvement. During last century the great zoological collections were in the main increased and augmented by the chance gifts of hunters and sportsmen, whose chief object in their expeditions was not zoology but what is termed 'sport.' Many valuable gifts are still received from such sources, but it is now recognised that we must not in these matters trust to the sportsman alone. The plan of attaching trained naturalists and experts in taxidermy to an expedition avowedly meant for other purposes is good, and is well ex-

emplified by Mr. Roosevelt's 'safari' in East Africa at the present time. We may hope that we may never again see an expedition without a single trained naturalist on its staff, such as the last Stanley led across Africa. A still better plan is to send out expeditions of trained naturalists to do definite pieces of work. Such expeditions as Andrews and Foster Cooper and Osborn to the Fayum for fossils, of Cunnington and Boulenger to the same region to investigate the fauna of the lake, or Wollaston and his companions to the Ruwenzori district, yield a harvest one hundred times more abundant than the best of other schemes.

Yet even here I would plead for a little more organisation. One must not suggest too rigid a scheme, and it is to be hoped that in the future, as in the past, there will always be found wealthy men willing to devote their energies to the advancement of zoology. Such work as has been done by Mr. Godman on the fauna of Central America, one of the richest regions in the world, and now, owing to his munificence, one of the best known. The stately array of volumes embodying these results is paralleled by the magnificent monographs in which the results of the Prince of Monaco's marine researches are recorded, and by the monographs of the Princeton Expedition to the Argentine, financed by one of the richest of the millionaires of the United States. We trust that such enterprises will always continue.

With regard, however, to expeditions financed from public funds which are sent out officially, it might be possible to have more international co-operation. Just as the members of the Geodetic Survey meet from time to time and determine the next step to be taken in the triangulation of the world, so it seems to me might the members of the chief museums of the world meet, say, triennially, and draw up certain thought-out plans for the exploration of the zoological world.

With regard to working out the material when collected, the existing museums of the world are too few, and their staffs are too small to deal not only with the huge collections which are constantly pouring into their buildings, but even with the accumulated stores already housed there. In our smaller state museums it is not uncommon to find men who are responsible for the whole of the Arthropoda. Only within the last few months I have had to try and find a curator for a Metropolitan museum who was expected to be a specialist in fishes, molluscs, and arachnids. Now is it possible to expect such men, able and zealous as they are, to accurately determine species in these vast and complex groups? My own feeling is—but I fear I shall carry no one with me—that we must specialise still further. I should like to see each of the great classes of the animal kingdom assigned to one of the great museums of the world. Just as an example—which is only an example, possibly a bad one—I suggest that all the type specimens of Amphibia be sent to one museum, say, if you like, that of Berlin or St. Petersburg; in return for this that museum should distribute to others its types of fish, birds, &c. Then, at this museum there would arise a series of specialists capable of deciding swiftly and accurately on the validity of the claims of any new species of amphibian that may be advanced. Again, a student of Amphibia, instead of wandering round the museums of the world if he wishes to study species, would find all he wants within the four walls of one building. When once the type is described and deposited, it would be the duty of the museum to distribute co-types and accurately named specimens of the same species to other museums in some recognised order. Smaller groups might be allocated to smaller museums, *e.g.*, the fleas to Tring and the ticks to Cambridge—at both of these places there are now specialists working out world collections of these pests. What I want is a world's Clearing House for animals. I know I shall be told that my suggestions can never be realised, that international jealousies would

prevent such a scheme being adopted, that I am proposing to fetter research. I admit the difficulties, but do not regard them as insuperable. When you recall the international Clearing Houses for the Postal and Telegraphic service, for the banking of the world, and when we reflect what private enterprise does, under the name of Lloyd's, for the shipping of the world, how it registers and describes and certifies with a minuteness not surpassed by any maker of species, each ship in the world; how, through its signal stations and by other means, it follows the daily course of each vessel, so that at any hour of any day it can state where, under normal circumstances, that vessel is, it does not seem to me impossible to come to some understanding as to dealing with the animals of the world. Only by some such means can we hope to cope with the problem before us.

One other fruitful source of 'waste of time' I will mention. That is the debatable matter of zoological nomenclature, more especially the questions of synonymy. The British Association at their last meeting passed a resolution on the proposal of Mr. G. A. Boulenger in the following sense:—

'The undersigned zoologists, whilst fully realising the justice and utility of the rule of priority in the choice of scientific names for animals, as first laid down by a committee of the British Association in 1842, wish to protest against the abuse to which it has been put as a result of the most recent codes of nomenclature, and consider that names which have had currency for a great number of years should, unless preoccupied, be retained in the sense in which they have been universally used. Considering the confusion that must result from the strict application of the rule of priority, they would welcome action leading to the adoption of a scheme by which such names as have received the sanction of general usage, and have been invariably employed by the masters of zoology in the past century, would be scheduled as unremovable.'

Mr. G. A. Boulenger expressed disapproval of the extreme application of the rule of priority in zoological nomenclature on the ground that it had already produced much mischief under the pretence of arriving at ultimate uniformity. The worst feature of the abuse of this rule is not so much the bestowal of unknown names on well-known animals as the transfer of names from one to another, as in the case of *Astacus*, *Torpedo*, *Holothuria*, *Simia*, *Cynocephalus*, &c., so that the names which were uniformly used by Cuvier, Johannes Müller, Owen, Agassiz, Darwin, Huxley, and Gegenbaur would no longer convey any meaning; very often they would be misunderstood, and the very object for which Latin or Latinised names were introduced would be defeated.

The International Congress of Zoology takes, I believe, a somewhat sterner view, but they are engaged in drawing up a list of names which they hope will be accepted for all time. I for one am prepared to accept them, and I am prepared to go further. I would ask the International Congress if, instead of drawing up a list of single species, or perhaps in addition to it, they would draw up a list of systematic monographs, the names in which may be regarded as final. After all, modern classification began with a book, and it would take no longer, or very little longer, to sanctify a book which may contain diagnoses of hundreds of species than to sanctify the single species. The idea is due to Mr. Cyril Crossland, and he suggests—he was working at Chaetopods—that such works as Claparède's *Annelides Polychètes du Golfe de Naples*, Ehler's *Die Borstenwürmer*, McIntosh's *Monograph of the British Annelids* be accepted. Possibly whole categories of books might be considered, such as the *Challenger Reports*, and especially *Das Tierreich*, the admirable volumes of which we owe to the enterprise of the Berlin Zoological Society. Such a scheme would certainly cause some minor injustices, but every scheme does that. The immense advantage of allowing a researcher to readily determine and give an accepted name to an animal he is investigating without waiting weary days in struggling through

a vast and scattered literature for the sake of synonymy would surely far out-balance any temporary injustice.

One last phase of my subject and I have finished with what I want to say on the subject of organising zoology. In Europe the great museums of our metropolitan towns are State museums, endowed by the State, managed by the State, and in Great Britain and Ireland staffed and curated by the State; that is to say, the officials at the museums are Civil Servants. Let us consider for a moment what that means, and let us take the British Museum, which, in its entirety, is second to none in the world as an example of a State museum.

The British Museum was established by an Act of Parliament in the year 1753 (26 Geo. II. cap. xxii). This Act sanctioned the purchase of collections and library of Sir Hans Sloane, that prince of collectors, for the comparatively insignificant sum of 20,000*l*. In fact, Sir Hans left his magnificent collection of natural objects, which, twenty years before his death, amounted to just under 70,000 specimens, his library of 40,000 printed volumes and 4,100 manuscripts, to the nation, on condition that 20,000*l*., about one-fourth of the estimated value of the collections, be paid to his executors. Under the above-mentioned Act 10,000*l*. were paid to each of Sir Hans Sloane's daughters, Mrs. Stanley and Lady Cadogan. The same Act provided 10,000*l*. for the purchase from the Duchess of Portland, heiress of the second Earl of Oxford, of the Harley collection of charters and manuscripts, which were then in the market, and other moneys for the purchase and repair of Montagu House, Bloomsbury, and for maintenance. The Act incorporated with the Museum the Cottonian Library at Westminster, which, by an Act of Parliament of William III.'s reign, was under the care of trustees, chief amongst whom were the Archbishop of Canterbury, the Lord Chancellor, and the Speaker; the money was raised by a lottery, and the museum was opened in January 1759, just 150 years ago.

Now it will be noticed that at its formal birth the museum consisted of about two equal parts—on the one hand books and manuscripts, and on the other what used to be called 'natural objects.'

The 'General Repository,' as the Act of George II. called it, was placed in the hands of a body of trustees, now forty-nine in number, three of them relics of William III.—namely, the Archbishop of Canterbury, the Lord Chancellor, and the Speaker of the House of Commons, are trustees by virtue of office. These three are known as the principal trustees; there are twenty-one other trustees in virtue of their office—*e.g.*, the Bishop of London, the President of the Royal Society and Royal Academy, and so on —one is appointed by the Crown, nine represent the families of donors, and fifteen are co-opted. So large and unwieldy a body cannot, as a whole, transact the business of a great museum, and they have largely delegated their functions to a standing committee of the three principal trustees and fifteen annually appointed representatives.

Now the manner of appointing to the museum is this. The junior members of the staff are selected as the result of examination, and when appointed they become Civil Servants. Not a bad thing in itself, but bad for a man of science. He, through no fault of his own, becomes entangled in red tape; above all, he must not make himself a nuisance; *trop de zèle* must be avoided, his enthusiasms tend to become checked, he is perpetually observing what is called 'official reticence,' and he perforce spends his days in performing routine work during routine hours. No amount of skill and ability—and the staff at the museum is both skilled and able—hastens his promotion. This is a matter almost entirely of seniority. In fact, the conditions of the Civil Service are incompatible with that freedom to research in any line that proves most suggestive, and with that absence of outside control which alone makes scientific research on a large scale possible.

The appointment to the senior staff, the keepers or heads of departments,

the Director of the Natural History Museum, and the chief librarian, are vested in the three chief principal trustees. This takes us back to the reign of William III. and the Cotton Library at Westminster. No doubt the then Archbishop, the then Lord Chancellor, and the then Speaker, both from propinquity and from their abilities and training, were quite the best men who could be found for this position of trust towards this library. Probably the present holders of these exalted positions—positions which they most worthily fill and which give two of them precedence after royalty in all Britain—are most fully endowed with the qualities which fit them to elect the senior staff for the library and for the collections of works of art and of antiquities at Bloomsbury. I doubt if the same eminent qualities enable them to deal equally satisfactorily with the higher posts in the Natural History Museum. If Parliament, or indeed any other body, were framing a scheme for the management of a great museum of science at the present time, I do not think it would occur to anyone that the holders of the exalted offices I have mentioned were specially fitted, either by the knowledge of the pressing scientific needs and problems of the moment or by their intimacy with the men of science of to-day, to be the most competent electoral body to choose keepers in geology, mineralogy, botany, and zoology. And, indeed, the existing arrangement has broken down. I do not know how long before Sir E. Ray Lankester's resignation of the joint posts of Director and Keeper in Zoology in December 1907, it became known to the trustees that that resignation was imminent, but I do know that it was talked about and written about months before that date. Yet after the resignation took effect one whole year elapsed before the trustees appointed a Keeper in Zoology; for twelve months there was no head of a department which contains collections unrivalled in the world. It took the trustees about six months longer to find a Director, and for about eighteen months the charge of this great museum of natural history was vested, under the trustees, in the Chief Librarian at Bloomsbury.

As Professor Ronald Ross could testify, after scientific research has placed it within the power of man to exterminate so deadly a disease as malaria, the real fight begins; and the real fight is to persuade the authorities to adopt and enforce the measures which are offered them gratis. There is a case in point, if I am not misinformed, on this continent at the present time. It has been known since the time of the making of the St. Gothard Tunnel that lasting and often fatal disease is caused by a small intestinal worm, known as the tunnel-worm or hook-worm. Within the last few years Dr. Wardell Stiles has shown quite clearly that the unhappy condition of the 'poor whites' of the Southern United States is due largely to their being affected by this hook-worm. Their bodies and their intellects are arrested in their development, and the adults amongst them are unable to understand the prophylactic measures he advocates, but the children can be taught if the proper organisation existed for teaching them. Many of the Southern States are friendly to the movement, and I know of no greater service that the central Government of the United States could confer upon the inhabitants of these southern States, in which, as is well known, President Taft takes the deepest interest, than that of detailing Dr. Stiles for several months a year to organise and control this movement. If this could be done, I believe—and I am here speaking of those things that I do know—the United States Government would confer on their own people a benefit as great as they conferred on other nations when they freed Havana of yellow fever and Panama of malaria.

In concluding this part of my address I wish to say as emphatically as I can that if science is to take its proper place in the polity of the nation we must endeavour to have men of scientific training, or at least of scientific sympathies, in the Government and also in the Government offices.

I cannot recollect the name of one single Minister trained in natural or

physical science amongst the numerous members of the British Governments of the last thirty-five years. It is not so very long ago—I am glad to say that one of the actors of my little story is still with us—that Sir Joseph Hooker, then Director of the Royal Gardens at Kew, was walking through the grounds with Mr. Ayrton, President of the Board of Works, which in those days was the Government Department responsible for Kew. They happened to run across Mr. Bentham, the great authority upon the classification of plants. Sir Joseph introduced him to the President, adding, 'he works in our herbarium.' 'Dear me,' said the President, 'I hope you don't get your feet wet.' Now I do not want for a moment to suggest that our present genial President of the Board of Works—whose official connection with Kew has been long severed—would not readily distinguish between an herbarium and an aquarium, but what I do wish to emphasise is that this ignorance of some of the most elementary details of scientific method exists in many of our rulers and in many of our permanent officials—not in all by any means, I know of some most notable exceptions—but in many. It is but human to distrust what we cannot understand, and it is this lack of understanding which is largely retarding progress at the present day.

III.

International Ocean Research.

As an example of international co-operation in scientific research I may take the investigations which have been going on for the last seven years in the Baltic Sea, in the North Sea, and in that greater Norwegian Sea which stretches from the western coast of Norway north to Spitzbergen and westward beyond Iceland and the Faroes. In this inquiry no less than ten nations—in fact, all those whose shores touch these seas—have had a share —England, Scotland, Norway, Sweden, Finland, Russia, Germany, Denmark, Holland, and Belgium—and since most of these countries have a special steamer equipped for research and under the command of men trained in scientific methods, it has been possible to collect a mass of facts connected with the seas of Northern Europe such as has never been got together before for any similar area of the ocean.

The aim of those responsible for the scheme of work was to obtain as complete a survey as possible of the physical and biological conditions of the seas in question. They wanted to know the direction of ocean currents, both superficial and along the bottom; the variations in the degree of salinity of the water in time and in space; the nature of the sea-bottom, and whether this could be correlated with the fauna, sessile or moving, found upon it, and whether this fauna reacted on the prevalence or absence of food-fishes; the influence of depth, salinity, and temperature on the fauna; the seasonal variations and fluctuations of the small floating organisms often called the plankton; the life-history of our food-fishes, where and when they deposited their ova; what became of the ova; the distribution of the larval stages; the age at which the fish become mature, and their average length of life.

Then, again, it was hoped that much could be learned about the influence of man's activity on the sea. The relative depletion of the fish population caused by different modes of fishing; the intensity of trawling; how often does the trawl pass over the same ground in a given time? The question whether or no the seas are being over-fished, and, if so, what measures can be taken to lessen this evil, either by close time, limiting the size of fish captured, or by artificial fish-breeding. Many of these last-named problems concern the legislator as much as the man of science. The function of the latter is to provide facts upon which the administrator may act.

Such a vast task as was set out by the International Council in 1902

has necessitated an immense organisation. Some eight or ten steamers are employed making periodic voyages, under the direction of trained men of science. Enormous numbers of temperature-readings, investigations into the speed and direction of currents, and chemical analyses of sea-water have been recorded, and thousands of samples of the bottom, of the animals and plants living thereon, of fish in all stages, millions of fish ova, have been collected and accurately determined. To work up such an amount of material has occupied the attention of a large number of naturalists. Each country has at least one large laboratory devoted to this work, and their results are co-ordinated and generalised by the central bureau. The English part of the work was entrusted by the Lords of the Treasury to the Marine Biological Association, and has been carried out under the direction of Dr. E. J. Allen and Professor Walter Garstang at our laboratories at Plymouth and Lowestoft.

Although all the ten countries are working upon what is, broadly speaking, a common plan, each has had its own special problems. In addition to carrying out the broad outlines of an international scheme, they have specialised along lines indicated by their own needs, and have attacked problems whose solution affected their own special food supply. Thus Norway, where the old open fishing-boat is being replaced by the modern decked trawler, has especially studied the cod and the saithe, the haddock and the herring, and has devoted much time and labour to the discovery of new fishing grounds, and has successfully done this along the Norse coast, in the Arctic circle, and on the banks between the Faroe Islands and Iceland. They have further established a trade in *Pandalus borealis*, allied to the prawns, which are taken in the deep waters off Norway, and are now to be bought in most fishmongers' shops in Great Britain.

In a similar way the Danes have tracked the eels as they leave the estuaries of the great rivers of Central Europe across the North Sea to the deep Atlantic off the West of Ireland, just beyond the 1000 fathom line. In these depths they spawn and the resulting larval form, the *Leptocephalus*, long thought to be a separate genus, lives there for a while, until, gradually changing into an elver, it retraces by some mysterious instinct its parents' path across the ocean and regains the fresh-water rivers which those parents had left.

The English share of the investigation is limited to that part of the North Sea which lies south of the latitude of Berwick, and for the most part to the western half of these seas and to the English Channel; the latter, as we shall see, is a very important area. The work, so far as it has been specialised, deals, in the North Sea, largely with the plaice, with the food of fishes generally, and with the character of the deposits forming the sea-floor, with the creatures growing thereon. In the Channel the English worker is entirely responsible for the study of the hydrography of the water, which, entering the North Sea through the Straits of Dover, contributes greatly to its mass.

As a result of Professor Garstang's investigations, an important spawning ground of the plaice has been located in the southern bight of the North Sea; the migration of both sexes has been traced to these grounds on the advent of the spawning season, and their return to their feeding grounds in the spring has been followed. During the spawning season it is usual to catch more males than females on the spawning grounds, possibly because at this time the female is inert and elusive, whilst the male is unusually active.

The course of the ova has been traced, chiefly by the Dutch investigators, as they drift towards the shallow fringe of coastal water, by far the greater number along the continental coast. Here the young fry grow up, and, after attaining a certain size, they leave the shallow coastal waters for the deeper seas off shore. Comparatively few of these, however, reach the

feeding ground of the Dogger Bank, and Garstang has been able to show that by carrying the young plaice in steamers and transplanting them at the proper time on to this rich feeding ground, their rate of growth can be greatly accelerated and thus their market value largely increased, just as Dr. Petersen has done in the case of plaice on Thisted Bredning.

A few years ago there was no reliable method of determining the age of fish. Petersen's method of arranging the measurements of a large number of specimens in a scale according to size, when they resolved themselves into certain groups, which were considered to coincide with age-classes, has been superseded by the discovery of Reibisch, Heincke, and others, that many of the bones, the scales, and the otoliths of fishes show annual age-rings, like those found in the trunk of a tree or in the horns of cattle. By laboriously counting the rings on the otoliths of thousands of plaice, Dr. Wallace and others have been able to determine their rate of growth, and to show that some specimens attain the age of twenty-five and even twenty-nine years. Similar investigations have shown that the sexes have a different rate of growth. The age at maturity is found to differ in different regions, but in the majority of cases Wallace found that the males are sexually mature (four to five years) a year before the female is capable of spawning (five to six years). We can now correlate age with size and with weight.

The migrations of the plaice and of other fish and their rate of growth depend, amongst many other factors, upon their food supply. And the nature of the food of fishes has recently been re-investigated in the North Sea. I give some of Todd's results, which were made by the examination of some thousands of fish of thirty-one species. Of these I select three—the cod, the plaice, and the dab.

Percentages of stomachs containing various kinds of food

Cod.

Size of fish in cm. .	0–15	15–30	30–60	60+
Pisces . . .	0 p.c.	11 p.c.	52 p.c.	67 p.c.
Mollusca . .	0	2	16	4
Crustacea . .	100	95	67	63
Polychaeta .	0	9	9	26

Plaice.

Size of fish in cm. .	0–10	10–20	20–30	30+
Pisces . .	0 p.c.	1 p.c.	5 p.c.	5 p.c.
Mollusca . .	17	66	76	84
Crustacea . .	57	16	13	11
Polychaeta .	38	37	51	42
Echinoderma .	0	20	13	6

Dabs.

Size of fish in cm. .	0–10	10–20	20–30	30+
Coelenterata .	0 p.c.	18 p.c.	18 p.c.	20 p.c.
Echinoderma .	0	26	25	2
Polychaeta .	30	22	20	10
Crustacea . .	70	30	35	61
Mollusca . .	2	48	57	65

These tables show what, of course, was more or less known before, that as a rule the young fry live very largely, and in many cases solely, on crustacea. To a great extent the supply of suitable food dominates the movement of the young fry, for nowhere is the truth of the Frenchman's definition of life, 'I eat, thou eatest, he eats,' with its terrible correlative, 'I am eaten, thou art eaten, he is eaten,' more true than in the sea. Later in life the fishes' taste alters, and with increased size they can tackle

animals whose calcareous deposits would seem to render them highly indigestible.

Very careful investigations have been made and are being made by Mr. Borley and Mr. Todd as to the distribution of the fauna of the middle and southern parts of the North Sea, and its relation to the depth of water, the varying degree of salinity, and to the texture of the bottom deposits. These results, however, have not been published, but I may go as far as to say that the inquiry shows that within the area investigated the texture of the sea floor has, on the whole, more influence on the distribution of the invertebrates of the bottom fauna than has depth, and that depth in the area in question seems to have more influence than salinity.

With regard to the character of the bottom deposits, it has been found by Mr. Borley that off shore and on the gently shelving continental coast the sea bottom is of a uniform character over wide areas, though on the western side it is more patchy; and it has proved possible to divide the samples taken into some nineteen main types, each characteristic of one or more of the areas into which the region has been split up. Only one or two details of this laborious work can be mentioned. One is that the texture or degree of coarseness of the ground in various parts of the sea is such as to suggest that the distribution of the finer grades of material, the finer sands and silts, is greatly influenced by the joint action of currents and tides. It is, for instance, known that in the southern part of the North Sea the main direction of the bottom current is to the north and then to the east; and examination of the deposits shows a regular diminution in the proportion of the coarser sands, a regular increase in the proportion of finer material, as we proceed from the Straits of Dover in a north-easterly direction. A remarkable fact in this connexion is the complete absence of silt from the sandy bottom west of the mouths of the great rivers Rhine and Maas. There can be no doubt that the presence of broad and shallow stretches of sand on the continental, but not on the English, side of the North Sea is one of the factors which has determined the distribution of the small plaice, which on the continental shores are so extraordinarily abundant, and on the English shores are relatively so scarce.

By means of bottles weighted with shot, so as to have about the same specific gravity as the surrounding sea water, Mr. G. P. Bidder has been able to trace slow currents moving over the bottom of the sea. The bottles are closed, and contain a postcard in many languages, offering a reward to whosoever returns the postcard, recording the latitude and longitude of the place it was trawled at, to our laboratory at Lowestoft. Attached to the neck of the bottle is a copper wire a foot and a half long. This wire trails along the bottom, the bottle itself floating about a foot and a quarter above the level of the ground. Slowly as the bottles are swept along, yet the distance they cover is sufficient to sharpen the free end of the wire to a needle point.

By these and by other methods it has been possible to trace the almost imperceptible but steady flow of waters along the bed of the sea. Without doubt these currents influence the distribution of the larval and young forms of all the creatures which live near the bottom, and especially influence the migration of food-fishes in their younger and less active stages, when they are swept helplessly along.

But these bottles have a double lesson to teach us: not only do they enable us to chart the slow streaming of the bottom water, but they give us to some extent a measure of the intensity of trawling in the North Sea. They have been refished in really surprising numbers. Commercial trawlers have retaken them at the rate of 58 per cent. per annum. In one area these bottles cast upon the waters were retaken, not after many days, but after very few. Out of 390, eighty-five were recovered in six weeks, and fifty out of 270 were trawled in five weeks, representing a local intensity

of fishing which if continued would give us between 80 per cent. and 90 per cent. of recaptures in a year.

Marked fish which have been liberated and recaptured tell the same story of intensity of fishing.

The intensity of fishing as indicated by the percentage of recaptures within twelve months of liberation is shown by the following table[1]:—

	Percentage	
Off shore	Fish under 25 cm.	Over 25 cm.
Dutch coast	23·7	20·3
Deep water, Southern Bight . . .	13·0	26·6
Leman Ground (liberated April and May)	18·7	17·4
Leman Ground (liberated December) .	—	21·0
Horn Reef outer ground	33·3	23·0

Obviously, since some fish are known to have been captured but not returned to the laboratory, the method gives a minimum estimate.

By applying the same method to the marking experiments of other countries as well as our own, Garstang[2] gave the percentage recovered within twelve months of liberation of fish over 25 cm. in length as from 4 per cent. on the Fisher Bank to 56 per cent. in the Skager Rak.

When we reflect on the chances of these marked fish dying or being eaten or losing their labels, it is surely a most remarkable fact, full of significance to the practical man, that in the North Sea marked fish of marketable size are recaptured at the rate of between 20 and 30 per cent. each year, and sometimes at a greater rate. It would seem that each square yard of the fishing grounds is swept by the trawl not once, but again and again each year.

Mr. Borley has conducted a large series of experiments to determine the vitality of fish after they have been captured by both the beam and the otter-trawl. It was necessary to determine the degree of injury caused by the actual trawling, the raising of the trawl, and the subsequent exposure on deck. The larger fish of both sexes were capable of resisting the damage to a greater extent than those of smaller size, and the relative resistance of the two sexes varied at different sizes, the male showing a decline in the increase of its vigour as it approaches maturity. One factor which is very deleterious to the fish is the presence of jellyfish in the trawl; these either smother the fish or possibly sting them to death; at any rate, the mortality of the fish is enormously increased when medusae are present in any numbers. The otter-trawl is also far more harmful than the beam-trawl, and exposure on deck to a hot sun is another constant source of death, one hour's such exposure in one series of experiments killing 99 per cent. of the smaller fish. In the ordinary commercial operation of trawling, whilst the fish are being sorted those that have no market value lie about on the deck of the vessel for at least an average period of one hour; hence it is extremely probable that when shovelled overboard practically all are dead or dying.

The work which has been done by our own special steamer has been supplemented by records carefully kept by certain selected captains of commercial trawlers, which sail from Grimsby or from Lowestoft. In this way the details of some 20,000 hauls have been examined, and their results tabulated by Miss Lee.

I have left myself no time to describe the important hydrographical investigations carried on by Mr. Mathews into salinity, temperature, etc., which show us the conflicting currents at the mouth of the English Channel

[1] Garstang, *North Sea Fisheries Investigation Committee Southern Area*, Report No. 1.

[2] *Provisional Report on the Natural History of the Plaice* (Committee B), *Procès verbaux*, vol. iii.

and how the North Sea in its southern part is supplied with water from the Atlantic through the Channel. The curious ebb and flow of the Gulf Stream, its periodic welling up and subsidence, closely connected as they seem to be with the migrations of the herring, cod, and haddock shoals, is another most important matter of investigation.

Neither can I tell you in detail of the immense amount of work which is being done by the other countries which share in the international scheme, by the Scottish Fishery Board, the pioneer in Great Britain of this sort of research. To the west our Channel work is beginning to get into touch with the more recently established Irish Fishery Board, and with the work carried on under the direction of Professor Herdman in the Irish seas.

The outcome of all this minute and continuous investigation will, in time, tell us whether or no the North Sea fisheries are being exploited in the most profitable way—a very important question for our country, for with a fishing fleet of 27,000 vessels, manned by 90,000 fishermen, who land 900,000 tons of fish a year, valued at 10,000,000*l.*, Great Britain takes 90 per cent. of what is caught in the North Sea. Some statistics indicate that there is a falling-off. The steam trawlers in 1905 landed 25,000 tons of fish less than in 1904, and in 1904 there was a similar shortage on the total of 1903. And yet 1903 was a year in which some crisis took place; the growth of the haddocks and the number of young haddocks were far less than normal, the Norwegian cod fisheries sank to a minimum, the French statistics showed the same feature in their fisheries off Iceland. In 1903, however, there were unusually large numbers of small plaice. The polar ice-field pressed down south, and seals, cetacea, and arctic birds left their usual quarters, and came south in some cases as far as Shetland. The gigantic climatic changes indicated by the above undoubtedly disturbed for a time the rate of increase and the rate of growth of the fish population of the North Sea, but they soon returned to their normal state. Compared with such mighty influences the fishing activity of man seems almost negligible, and Dr. Hjort for one thinks that 'the productiveness of fish' 'may be regarded as independent of the interference or fisheries of man.' I am not sure that this is so. Taking large areas and all fish into consideration, it may be true; especially it would seem to be so of some species, such as the herring, the saithe, and the cod; but in certain areas and with certain fish, such as the sole and the plaice, man's activity has undoubtedly decreased the number.

Although the researches of the last few years have immensely increased our knowledge of what is going on in the sea, they have, like an ever-widening circle, but increased the number of problems which await solution. It is earnestly to be hoped that the work may go on on at least its present basis. The business man, always on the outlook for a dividend, has sometimes complained that some of our inquiries do not seem to him practical, but he must have patience and faith. A few years ago no knowledge could seem so useless to the practical man, no research more futile than that which sought to distinguish between one species of a gnat or tick and another; yet to-day we know that this knowledge has rendered it possible to open up Africa and to cut the Panama Canal.

And here, if I may quote the words of the author of the Maccabees: 'And here will I make an end.'

'And if I have done well, as is fitting the story, it is that which I desired; and if slenderly and meanly, it is that which I could attain unto. . . . And as wine mingled with water is pleasant and delighteth the taste: even so speech, finely framed, delighteth the ears of them that read the story.'

'And here shall be an end.'

The following Papers and Reports were then read:—

1. *On the Osteology of the* Lophobranchii. *By* Professor H. Jungersen.

The skeleton of the *Lophobranchii* has hitherto been most unsatisfactorily examined. The cranial structures, especially the suspensory apparatus, the gill-arches and the scapular arch have been incorrectly interpreted by all previous authors. In the skull parietals and opisthotics are wanting; the pterotics are greatly developed, reaching below to the basioccipital, and preventing the exoccipitals from meeting the prootics. These two features, together with the prolongation of the anterior part of the skull (mesethmoid and vomer), the *Lophobranchii* have in common with the *Solmostomidæ*, the *Fistularidæ*, the *Aulostomidæ*, and the *Custriscidæ;* these families form with the *Lophobranchii* one natural group, the '*Solenichthyes*' of *Regan.*

The suspensory apparatus contains all the typical parts; only the metapterygoid is absent. The lower jaw is composed as usual, but the angular is very small; by some authors it was supposed to be wanting. The three opercular bones are all present; the subopercle is hidden by the opercle, and therefore easily overlooked (especially in *Hippocampus*).

Two infraorbitals are found in the Syngnathine, three in the Hippocampine group. The hindmost infraorbital corresponds to the preorbital in other bony fishes. The infraorbitals do not contain any canal for the lateral line, neither are any of the other cranial elements nor the scutes of the body provided with lateral line-canals. The hyoid consists only of four pieces (*Siphonostoma, Syngnathus, Hippocampus*) or three (*Nerophis*). In the first case the ceratohyal seems to be absent, in the latter also the upper hypohyal is wanting. Most Lophobranchs have two branchiostegals, but *Nerophis* has only one, which distally bifurcates. Glossohyal and urohyal are always present. In *Hippocampus* basibranchials are totally absent; in other *Lophobranchii* the two anterior ones are found. The gill-arches are slender and feebly ossified, and show a somewhat rudimentary condition. In most *Lophobranchii* the three anterior arches have epibranchials, the second and third besides possess pharyngobranchials; but the epibranchials are widely separated from their ceratobranchials. In *Nerophis* no epibranchials are found, and the pharyngobranchials are reduced to one on each side, probably representing that of the second arch. The hypobranchial of the first arch is wanting in *Siphonostoma* and *Syngnathus,* but present in *Hippocampus* and *Nerophis.* An interesting step towards the condition in Lophobranchs is shown by *Fistularia* and *Aulostoma* when only the three anterior arches possess epibranchials, which, except that of the first arch, are separated from their ceratobranchials; but these genera have preserved the fourth pharyngobranchial. Also a reduction of the basibranchials is apparent here as well as in *Solenostomus.*

The scapular arch is cartilaginous to a much greater extent than is the case in other Teleosteans, but a small ossified scapula is found as well as a coracoid. The coracoid has been interpreted as two 'interclavicles' (W. K. Parker, 1868) or as one 'interclavicle' (Smith, 1895); the scapula has been totally overlooked or considered as the uppermost of five basals (Goodrich, 1909). In reality there are four basals, as in most Teleosteans. The distal ends of these bones are on each side provided with two or three processes bearing irregular flat expansions, which lean against the dermal skeleton and the dermal part of the clavicle. In this way the whole part on which the pectoral fin-rays play is immovably fixed between the lips of the slit in the armature for the pectoral fin. Through the narrow apertures left the tendons pass from the pectoral muscles to the base of the fin-rays, thus arranged between and conducted by a system of 'coulisses.' In this way the whole scapular system is strengthened by

the dermal armature, and the extremely thin and fragile, mostly cartilaginous, apparatus is rendered capable of giving origin to such powerful muscles as really are found here.

The three anterior vertibræ are immovably joined together, their neural arches being firmly bound by sutures with long dentations; besides, the two anterior are fixed to the expanded clavicle. The same immobility is found in *Solenostomus* without the clavicle here taking any share in the fixation.

The vertebræ bearing the interspinous bones for the dorsal fin are provided with secondary transverse processes close behind the primary ones; thus the surface is enlarged, which gives attachment to the powerful muscles of the dorsal fin, the chief agent in swimming. The upper ends of the (bisegmented) interspinous bones bear flat expansions, on which the plates of the armature rest; through the small apertures left the tendons of the fin-muscles pass in a similar way as in the pectoral fin. As modified interspinous bones the nuchal plates may be regarded, a view which seems to be corroborated by the facts found in *Aulostoma* and *Fistularia.* Two nuchal plates are present in the Syngnathine group; a third is added behind these in the Hippocampine group; but the first, present in *Hippocampus*, the 'Corona,' and *Solenognathus*, is wanting in *Gasterotoheus* and *Phyllopteryx*.

---

2. *Texas Fever in Cattle: its Cure by the Use of Drugs.* *By* Dr. S. Hadwen.

---

3. *Report on the Occupation of a Table at the Zoological Station, Naples.*—See Reports, p. 191.

---

4. *Report on the Index Animalium.*—See Reports, p. 195.

---

5. *First Report on the Feeding Habits of British Birds.* See Reports, p. 196.

---

6. *Report on Experiments in Inheritance.*—See Reports, p. 195.

---

7. *Nineteenth Report on the Zoology of the Sandwich Islands.* See Reports, p. 197.

---

8. *Interim Report on Zoology Organisation.*—See Reports, p. 198.

---

9. *Report on the Occupation of a Table at the Marine Laboratory, Plymouth.*—See Reports, p. 198.

---

10. *Interim Report on Experiments on the Development of the Frog.*

MONDAY, AUGUST 30.

The following Papers were read:—

1. *Palæobiology and the Age of the Earth. By* Professor A. B. Macallum, *F.R.S.*

---

2. *The Pre-Nuptial Plumage in* Calidris arenaria. *By* C. J. Patten, *Sc.D.*

It may be well to state very briefly what led up to this investigation. Repeated observations on the Sanderling during its vernal migration show that the species occurs in varying numbers throughout the breeding-season on different parts of the British coast. A certain proportion of the migrants, pushing northward, appear to sojourn with us during the summer. These birds, while assuming what might easily be mistaken for the nuptial plumage, show no evidence that they remain to breed, for the flocks keep to the coasts and do not split up into pairs. Based upon the above data I have elsewhere put forward the hypothesis that the birds were immature (*vide Naturalist,* 1909, pp. 84, 85). Here I hope further to strengthen this hypothesis by direct objective evidence obtained from an examination of the plumage-markings. The rich variegated markings of chestnut, brown, and black, which appear on the head, neck, breast, back, and wings, are found in the summer plumage in Sanderlings in all ages, after the first winter plumage. It is generally known as the nuptial plumage. When, however, the tertials of those birds which tarry with us till late June, July, and the beginning of August are examined it may be noticed that they, *like the tertials of the first winter plumage, are relatively short,* the longest not reaching to the tip of the fourth primary feather, the wing being folded in the natural position. By far the majority of Sanderling which I have collected in late spring and summer have short tertials, and to such plumage I give the name of *pre-nuptial,* from its close resemblance to the true nuptial plumage which it precedes. But a few specimens collected towards the end of April and in early May, from small flocks, showed on examination to have *longer tertials which reached halfway between the tip of the fourth and third primary, and in some cases almost to the tip of the third primary.* Such birds I believe have assumed the adult nuptial plumage of the second or subsequent springs. This plumage follows the plumage of the second or subsequent winters, in which the long ashy-grey tertials are easily distinguishable from the darker shorter ones of the first winter plumage. With reference to the flocks which may be seen early in August (*before the advent of the birds of the year*), I may cite that out of a large flock which appeared on the Dublin coast on August 7, 1900, I secured several, all of which had short tertials; moreover, the birds were very fat and in good condition, and showed no signs of having gone through the task of hatching and rearing a family, while their liveliness on the beach indicated that they were not suffering from migration fatigue. Such evidence tends to disprove the idea that these early August birds have descended from their breeding-haunts in northern regions. They have probably remained throughout the summer, but at the beginning of August have mustered into large gatherings. It may be added that in both pre-nuptial and true nuptial plumage there seems to be a considerable amount of variation in the distribution and intensity of the rich brick-red colouration which is so characteristic. Both plumages are assumed by an extensive vernal moult, involving not only the feathers of the upper and under-parts, but also the wing-coverts. It would appear, however, that the winter primaries are not shed.

---

3. *The Germinal Disc in Naturally Incubated Eggs of* Passer domesticus. *By* C. J. Patten, *Sc.D.*

Due reflection on the facts that nests (or, in the case of those birds which make no nests, the soil on which the eggs are deposited) vary to an extraordinary extent in their heat-retaining properties; that the protecting egg-shells vary strikingly not only in their thickness but in their porosity and other structural peculiarities; and lastly that avian embryos vary to a considerable extent as regards their vitality when heat is withdrawn from the shell, has led me to think that the method of studying avian embryology by means of the artificial incubator is not always the most reliable. In making this statement I am fully sensible of the successful issues which have been brought about by artificial incubation. Not only the eggs of the Domestic fowl, but also those of wild birds of markedly different nesting habits can be hatched out so that the chicks are healthy and continue their post-natal growth vigorously. Still, when using the incubator extensively one frequently finds that monstrosities arise as well as ill-defined developmental phases. That birds allow their eggs to cool down for short periods I have little doubt, this taking place in some species much more than in others. Furthermore I have noted how some birds are more anxious than others to return to the duty of hatching, due allowance being made in the case of close sitting towards the end of incubation. It would thus appear that brief periodic coolings of incubating eggs in a state of nature might prove beneficial rather than otherwise, and in support of this theory I would state that in my experience with the incubator I have found many more irregularities in the developmental phases of avian embryos when submitted to hyper-normal than sub-normal temperatures. With such preliminary remarks I may now briefly indicate the changes which I observed during the first six hours or thereabout in a clutch of naturally incubated eggs of the house-sparrow (*Passer domesticus*). The site of the nest was so conveniently near my laboratory that not more than about two minutes was required to transport an egg for examination. On the fifth egg being laid the mother bird began to sit. One egg was then removed and the germinal disc, circular in outline, was seen to be 2·5 millimetres in diameter. The pellucid area was very distinct and contrasted strongly with the external opaque area, both being almost circular. The second egg was removed after the bird had been sitting for about forty-five minutes. Examination showed a well-defined primitive streak with little of the embryonic shield remaining. Viewed from above the primitive streak was seen scored along its entire length. The posterior end of the streak falls short of the posterior border of the area pellucida. The diameter of the disc measured four millimetres. The third egg was allowed to incubate for fifteen minutes longer. The two zones were slightly oval, though the entire disc remained circular. The posterior part of the primitive streak was thickened into a distinct round knob which reached to the posterior end of the zona pellucida. The diameter of the entire disc measured six millimetres. The mesoblast had invaded laterally the zona pellucida, and a faint trace of the neural groove was seen to commence in front of the primitive streak. The amniotic fold was also faintly discernible.

The fourth egg was removed an hour later. On the disc was seen the dorsal opening of the neurenteric canal situated between the front of the primitive streak and the posterior end of the neural canal. The anterior half of the latter had not yet appeared. The entire disc had not increased to a larger size than the preceding one.

Opportunity was not afforded me of removing the last egg until four more hours had elapsed. Examination then showed that the entire disc was no larger than the preceding ones, but the neural groove had appeared along its entire length and the amniotic fold was quite distinct. Comparing these

phases with such in the fowl's egg, artificially incubated, it is seen that in the latter they do not appear so early. This may in part be associated with the longer time that the fowl takes to completely incubate its eggs, but it is noteworthy that the discrepancy in the time of the appearance of the corresponding stages of development in the case of the sparrow's eggs may be further bridged over if one assumes that the naturally well-constructed heat-retaining nest allowed development to proceed during the laying of the clutch, that is to say prior to the period when the mother bird took on the task of incubating.

---

4. *British Pleistocene Canidæ. By* Professor S. H. Reynolds, *M.A.*

Three species are found, the wolf, fox, and Arctic fox. There is no evidence of the existence in Britain, in Pleistocene times, of any animal that could be called a dog. The wolf, which is first found in Pliocene strata, abounded in England in Pleistocene times, its bones having been recovered from 47 out of the 51 deposits referred to. There are few records from the Scotch Pleistocene, probably owing to the lack of caves, but this explanation will not account for the scanty and generally fragmentary character of the wolf-bones found in Ireland, where they are known from only two Pleistocene caves. The distribution of the fox in cavern deposits is almost identical with that of the wolf. The Arctic fox has been recovered at present from only four English Pleistocene deposits, and one Irish. The find described as *Lycaon anglicus* is thought by the author to be better regarded as a somewhat abnormal wolf.

While apart from any difference in size the skull of a fox is readily distinguished from that of a wolf or dog by the depressions in the post-orbital processes of the frontals, it is extremely difficult, if not impossible, to find any valid distinctive character as between dogs and wolves. The most useful character, for which we are indebted to Studer, is the orbito-frontal angle. He regards skulls in which this angle measures 40°-45° as belonging to wolves, and as belonging to dogs skulls in which the angle is greater than 45°. The author's measurements, while confirming Studer's contention that the angle in question tends to be decidedly less in the wolf than in the dog, show that the distinction is not absolute, and cannot be relied on in all cases.

---

5. *The Rôle of Visual Function in Animal and Human Evolution. By* George M. Gould, *M.D.*

The author sought to bring to better recognition the difficulties encountered in the creation and the adaptation of the eye to the environment, a large and intimate part of the environment being the animal and human body itself. The difficulties were grouped into those which relate to:—

1. The embryology and optics of the eyeball.
2. The *rôle* of vision in the development of self-motility of the body.
3. The progress from divergence to parallelism of the optic axes, or from laterality to forward-looking.
4. The adaptations consequent upon the assumption of the vertical posture of the body.
5. The development of the shading mechanisms of the retina.
6. The struggle against astigmatism and other forms of ametropia, accommodational failure, cataract, ocular and systemic disease.

Embryology is suggestive in the facts that the essential part of the eye, the retina, is cerebral substance pushed without the skull—'the brain comes out to see'; and, secondly, that at so early a period eye and muscular tissue are coincidently developed. *Ubi motus ibi visus* thus illustrates that

vision is a condition of self-motility. Those individuals and types not securing the better vision are those excluded. The difficulties of creating the eye were so great that the unfit were usually those visually unfit. Ascent of types to fuller or higher function is measured and also largely caused by the slow approach of the visual axes from extreme divergence to the parallelism of *Simiae* and *Homo*, fighting-power and individualism proceeding *pari passu* with every approach to parallelism of the visual axes.

A still more profound visual difficulty was overcome when it was found visually possible to guide and render habitual the change from horizontality of the animal body to verticality, partly effected in the *Marsupialia* and the *Simiae*, but successful in *Homo*. It was plainly impossible to create visual organs fitted equally well to serve animals at once horizontal and vertical; even the intermediate or 45° animals, as the kangaroo, are zoologic failures. With the verticality of *Homo* severe labour was thrown upon the lumbar portion of the spinal column, but the influence of the ocular function of civilisation was required to produce the 80 per cent. of cases, among our educated classes, of lateral spinal curvature. With *Homo* came early the use of the hands as manipulative tools, the development of righthandedness and lefthandedness, the formation of language, and the location of the cerebral centres of righthandedness and speech in one cerebral hemisphere. Inevitable was also the development of righteyedness governing righthandedness, and of lefteyedness in lefthandedness. With the high differentiation and perfection of visual function in vertical man arose the necessity of the fifteen shading mechanisms of the retina upon which its greatest sensitiveness depends. One of the most necessary of the shading devices is the placing of the border of the upper lid across the cornea at the upper edge of the pupil, whence arises astigmatism, a source of one of the most formidable of the ills of humanity. Direct and indirect consequences are the functional diseases seemingly of cerebral, digestional, and neurological nature, but really constituting the chiefest cause of exclusion of affected individuals from the evoluting phylum. The cerebrum is the inherited average of all past experience with approximately perfect visual images. When a highly variant individual stimulus comes in collision with this massive inheritance of the normal past, the individual and his morbidity must both be re-fused —unless it be normalised artificially—as is possible in this case.

TUESDAY, AUGUST 31.

The following Papers were read and Resolutions passed:—

1. *On the Distribution of the Rotifera.* *By* Charles F. Rousselet, *F.R.M.S.*

The results of recent investigations point more and more to the fact that the Rotifera enjoy a cosmopolitan distribution which is not limited to continents, but extends to all places on the surface of the earth where suitable conditions prevail. Wherever search has extended in Europe, America, Africa, India, China, Australia, and even the North and South Polar regions, the same genera, and even species, have been met with, and it is not possible to speak of any typical or peculiar Rotatorian fauna for any continent, zone or region.

It is true that some species have so far been found in one locality only, but that must be attributed to the fact that no country has as yet been thoroughly explored. The greatest number of species are known from Europe, and in particular from England, evidently due to the fact that in this country the greatest number of searchers have been at work on this group.

In the United States the Great Lakes have been explored by Jennings, and the Illinois River by Prof. Kofoid, and some few other regions by Kellicot, Hempel, and others, and, though about 300 species have been recorded, no very peculiar and distinctive American forms have been revealed.

In Canada, unfortunately, no one has yet been found to take up their study, and the Rotatorian fauna of the Dominion therefore remains quite unknown.

From South America 80 species have been recorded by Prof. Von Daday in plankton collections made in Paraguay, of which three only are described as new, all the others being already known in Europe.

During the British Association meeting in South Africa in 1905, I myself collected in various widely separated localities—Capetown, Orange River Colony, Transvaal, and Rhodesia—in all 63 species, all of which, except one, were already known in other parts of the world. Even in the Zambesi River, where I obtained 38 species in pools just above the Victoria Falls, all of them without exception were already known outside Africa. Gunson Thorpe, W. Milne, Thos. Kirkman, and James Murray have recorded about 100 more species from other parts of South Africa, of which less than half a dozen were new forms.

From Central Africa I have examined collections made by Dr. W. A Cunnington in Lake Tanganyika and adjacent rivers, and, though this material was very poor in Rotifera, I obtained about 40 species, all known already in Europe.

In moss collected in the Sikkim Himalaya in India, Mr. Jas. Murray observed 36 species, mostly Bdelloids, of which five only were as yet unknown in Europe.

As regards distribution in Arctic and Antarctic regions, I may mention that Dr. Bergendal has recorded 82 species, belonging to 38 genera, from Greenland, where the pools and shallow lakes are frozen, often to the bottom, for eight months in the year. With the exception of a few new species found there for the first time, all these forms belong to the ordinary European fauna.

In collections from two lakes in Iceland, Dr. Wesenberg-Lund found nine species of Rotifers, all having a wide distribution in Europe.

From Ross Island, in the Antarctic continent, Mr. Jas. Murray has quite lately brought back evidence of a considerable Rotatorian fauna, mostly Bdelloids, which he found living in large patches at the bottom and also on the surface of shallow lakes formed during the short summer period ; most of these are common forms in Europe, Africa, India, and elsewhere, but a few will be described, as new species. During the cold weather these Bdelloids contract into little balls and are frozen solid, but revive immediately the ice melts. *Hydatina senta*, a large and very cosmopolitan species, was found in abundance in one of the lakes on Ross Island.

The very erratic appearance of rare or uncommon species in widely separated places seems to show that distance is no obstacle to their distribution, provided only that they find suitable conditions. A few examples of such erratic distribution may here be cited :—

Trochosphæra æquatorialis was found by Semper in ditches which intersect rice fields in the Philippine Islands in 1859 ; its next appearance was in 1889 in Australia, where Gunson Thorpe found this same spherical Rotifer in a pond of the Botanic Gardens in Brisbane; other examples were given.

These examples of the occurrence of rare species of Rotifera in widely separated and distant lands will suffice to show the extreme range of distribution which these very minute but highly-organised animals have attained, and this in spite of the fact that they are essentially fresh-water forms and that the sea is to them an impassable barrier.

As regards temperature it appears that, though the majority prefer a

moderate degree of heat, there are many species which live equally well in cold Arctic and Alpine lakes, where the temperature is only a few degrees above freezing point, and in the warm lakes of tropical countries. But there is no doubt, also, that some species are able, slowly no doubt, to accommodate themselves to much higher temperatures, and Dr. R. Issel has found 10 species, ordinary kinds, living in hot springs near Padua in Italy, at temperatures ranging between 35° and 45° Centigrade.

On the other hand, in Arctic regions, where all water becomes solid during the greater part of the year, the Rotifers, or their eggs, survive the most severe frost, and come to life again as soon as the ice melts. Mr. Jas. Murray informs me that in the Antarctic regions he found at the bottom of a lake on Ross Island, which had been frozen solid for an unknown number of years, a layer of mud containing frozen Bdelloid Rotifers, which recovered and came to life immediately they were placed in water. In order to reach this bottom layer Mr. Murray had to make a shaft 15 feet deep through solid ice. This, I think, constitutes a record of endurance for Rotifera.

To account for such a distribution over the whole of the globe, it has been supposed that most species of Rotifera can be dried up and their bodies carried by the wind, as dust, for long distances, and then come to life again on landing in suitable surroundings. This is, however, a very erroneous generalisation of the fact that a very few species of Bdelloid Rotifera, and in particular *Philodina roseola,* as first shown by Davis, are capable of secreting, when drying slowly, a gelatinous envelope in which they can resist drought for many months, and come to life again on being placed in water.

This property appears to be confined to the above species and some moss-haunting Rotifers of the genera Philodina and Callidina, which habitually live on moss that periodically dries up and then becomes wet again by rain. Species living in always submerged moss do not appear to acquire this property. Another condition of the formation of the protecting gelatinous envelope is that the desiccation should be slow, otherwise it cannot be formed and the animals die in a short time.

My experience has shown me, and is confirmed by the experiments of D. D. Whitney, that the vast majority of Rotifers die immediately on being dried and do not revive after complete desiccation, but their eggs, and in particular their resting eggs, with more resisting shell, can stand a prolonged state of desiccation and also freezing, and can therefore readily be transported by the wind or by aquatic birds and other animals, and will hatch when deposited in suitable pools of water.

In my opinion it is by this means that the cosmopolitan distribution of the Rotifera over the world has in the course of time been brought about.

Resolutions.

(i) The Zoological Section of the British Association wish to record their sense of the danger caused by the approach of the Norwegian rat, which threatens the wheat industry of Western Canada, and to urge the Governments concerned to take immediate steps to organise the extermination of this dangerous pest.

(ii) In view of the enormous importance of the Fisheries of Canada in connection with her prosperity and her rapidly developing position as the great resource of the food supply of the Empire, and appreciating the danger of exhaustion which menaces certain of the Fisheries, the members of the Zoological Section of the British Association for the Advancement of Science now meeting in Winnipeg, desire to congratulate both the Dominion and Provincial Governments upon the work already accomplished in con-

nection with the study of the food fishes, upon the establishment of a Marine Biological Station on both the Atlantic and Pacific coasts, and upon the co-operation with the Government of the United States in an international Commission, from whose labours much may be expected. At the same time, the members of the section are of the opinion that further and more extensive efforts in all these directions are urgently needed if certain of the fisheries, notably that of the Pacific salmon, are to be maintained, even at their present condition of productiveness. For the framing of satisfactory and effective regulations for the utilisation and conservation of the food fishes, a complete knowledge of their life-history is absolutely necessary, and the section desire to impress on the Governments concerned the immediate need for an extensive prosecution of investigations along this line, for greater facilities for the scientific study of the fisheries, especially those of the Pacific coasts, and for a continued co-operation of the Dominion Government with the Governments of the Provinces and also those of the United States in all efforts looking towards the conservation of the fisheries, one of the most valuable natural resources of Canada.

---

2. *Autonomy in the Crustacea.* *By* Dr. J. Pearson.

---

3. *On the Distribution of Fresh-water Eels.* *By* Dr. Schmidt.

Leaving aside the interesting question how far eels penetrate at different places into the land through the rivers, the distribution in the regions close to the coast has been principally considered. In working out this distribution of the genus *Anguilla*, throughout the world, only that part which treats of the Atlantic species is so far completed. Though uni- and vari-coloured species are found in the Indian and Pacific regions, only two uni-coloured species, *A. vulgaris* (Tart.) and *A. chrysypa* (Raf.), occur in the Atlantic region, the former in the eastern, the latter in the western part.

Fresh-water eels are lacking on the Pacific shores of South and of North America, and on the Arctic coasts. On the western Atlantic shores they are found from the southernmost part of Greenland, at Labrador and eastern Canada, along the coasts of the United States and Mexico, the West-Indian Archipelago and Guiana.

They are absent from the southern coast of the Caribbean Sea and from the coasts of South America south of Guiana—*i.e.*, in the large river-systems of Brazil and Argentina. On the east boundary of the Atlantic they are lacking on the north coast of Asia and Russia, but are found from North Cape southwards along the coasts of Europe, on all the coasts of the Mediterranean—the Black Sea excepted—and on the north-western part of the African coast. Here they disappear from the region of the Rio del Oro, and are absent from all the west coast of Africa—*i.e.*, in the large river-systems of the Niger and the Congo. In South Africa, near Cape Agulhas, we again meet fresh-water eels, also on the east coast of Africa as far north as Somaliland (whether they are found at the coast of the Red Sea and South Arabia cannot be stated with certainty); further, at the south coast of Asia and on the islands in the Indian Ocean. The relation between the *Anguilla* species occurring here (among which there are one-coloured as well as vari-coloured), and the Atlantic *A. chrysypa* and *A. vulgaris* has not yet been fully ascertained.

Besides, the two Atlantic fresh-water eels occur in the oceanic islands: Bermudas—Iceland, the Faroes, the Azores, Madeira, the Canaries—and, what deserves especially to be pointed out, they are found on islands where other fresh-water fishes are completely lacking. They are not to be found on the Cape Verde Islands, nor on any of the oceanic islands south of the Equator.

Having now stated the facts, we proceed to try an explanation of these, confining ourselves to the Atlantic species. It has been shown that the Atlantic fresh-water eels live in tropic, in warm, and in cold temperate, even in Arctic regions; but just on account of this astonishing power to submit to the most varied outer conditions their distribution appears somewhat incomprehensible. Why do they stop suddenly southwards so that the greater part of South America and West Africa are entirely destitute of eels in spite of the fact that some of the largest and most fish-abundant fresh-water systems are found here, and many places apparently would offer excellent conditions for their thriving? And why do they occur in the oceanic islands, in which fresh-water fishes otherwise are lacking?

Before answering these questions, and some others to be mentioned later on, it will be necessary to refer to some of the recent results of sea-investigations. It is now a well-ascertained fact that the sensibility of a species of fish to its surroundings may vary a great deal during its growth and at its spawning-time; during the latter its requirements as to depth, temperature, and salinity may be very different from those during its growth; therefore its distribution during spawning may often be very different from that during the growth; and it may be the conditions for spawning which are the chief factors in determining the distribution of the species afterwards. Investigations made since 1904 with the Danish investigation steamer *Thor* and the Irish *Helga* in the Atlantic west of Europe have shown that the European fresh-water eel propagates in the Atlantic far from the coasts, and that its propagation requires large depths (at least 1,000 metres), besides a high salinity, more than 35·20 per cent., and a high temperature of the water, at least 7° C., at a depth of 1,000 metres. These facts render the distribution and migration of the eel in the northern part of Europe quite comprehensible.

To apply these conditions to the whole region. On looking at a chart on which the temperatures at a depth of 1,000 metres are given, the distribution of the Atlantic fresh-water eels suddenly becomes quite clear. We see that the 6° and 5° isotherms run from the West Indies eastwards over to Cape Verde, so that the whole southern part of the Atlantic has a lower temperature at 1,000 metres depth. Off the greater part of Brazil the temperature is even only between 3° and 4° C., off the west coast of Africa a little higher, for the greater part between 4° and 5°. On the Pacific coast of America the temperature in deep water is also low, in no place reaching 7°, being in the greater part below 5°. We understand at once that the want of eels in all the large fresh-water systems of South America, the western North America, and West Africa is due to the fact that the temperature of the adjacent seas is too low to permit of the propagation. Therefore no immigration of young eels to these regions is possible. We may say, although it sounds almost paradoxical, that it is the cold which prevents these regions, which contain some of the warmest countries upon earth, from being inhabited by fresh-water eels.

On the East of Africa, in the Indian Ocean, as well as on the South of Asia, we meet with a higher temperature. And here again fresh-water eels are found, though not the same species as in the Atlantic region.

Taking for granted that the eels propagate out in the sea, we understand why they may be present in oceanic islands, where no other fresh-water fishes are living, and looking at the temperature curves we understand why only the oceanic islands lying north of the Cape Verde Islands are inhabited by eels; only these lie inside the region where the temperature in the depth is high.[1]

[1] Here it may be remarked that high temperature and high salinity are always connected in the great depths of the oceans. Thus it is impossible to ascertain whether the one or the other factor, or both combined, are determining the propagation of the eel.

Two questions to be answered are the following:—Why are eels absent from the Black Sea, while they are to be found in the innermost parts of the Baltic?

And why are eels present at the northern coasts of the Mexican Gulf and the Caribbean Sea, but absent from, or, at all events, exceedingly scarce, on their southern coasts?

Concerning the Black Sea, it is a fact, established many years ago, that not only this sea, but all the rivers flowing into it, are totally devoid of eels. Now, the temperature of the depth, as shown by the chart, is high, 9° at 1000 mètres; but other factors prevent the spawning and the immigration from the Mediterranean, where, as a matter of fact, eels do spawn. In the first line spawning must be prevented by the large quantities of sulphuretted hydrogen found in the deep water; and, besides, the salinity here, without doubt, is too low, being only 22 per cent., whereas it ought to be at least 35·20 per cent., judging from what is the case with the Atlantic. Immigration of young stages from the Mediterranean must be very difficult, by reason of the narrow passages leading into the Black Sea; only a small number might be able to pass, and spreading suddenly over a large area, after passing, their chances to settle on the right places may be rather small.

Concerning the second question, about the Mexican Gulf and the Caribbean Sea, we find that in both the temperature at 1000 mètres depth is only from 4·5° to 6°. Thus it is not probable that fresh-water eels would be produced here; in fact, we have no observations pointing in that direction; and the relatively small amount of eels yielded by the central region of the United States (the Mississippi region), the apparent scarcity of this fish in Mexico, and the total disappearance east of Tamaulipas, seem to exclude the possibility of any production, at all events of any large production. Thus, the presence of eels at the northern boundaries is most likely due to immigration from a centre of production lying elsewhere.

An endeavour has been made to determine where the Western Atlantic eel (*A. chrysypa*) is found, and also to get an idea of the frequency of its occurrence, of its quantity or scarcity in the different localities, also in regard to its penetrating up into the land.

In the southernmost part of Greenland the eel is very scarce. Its rare occurrence in that locality was referred to by Fabricius (1780). For many years we had no confirmation of his statement, but recently my endeavours to get a Greenland specimen were crowned with success; one specimen was captured and sent to the Museum of Copenhagen; it proved to be the *Anguilla chrysypa*, the American species. In Labrador it is found, but, apparently, not in great numbers; in Newfoundland it seems to commonly occur, since on the west coast it is caught in traps, and exported, to some slight extent, from this colony. It is found in great numbers in the eastern parts of Canada and the United States; it also appears in numbers in the northern portion of Mexico and in the West Indies.

Regarding the occurrence in the interior of the continent, statistical statements about the fisheries show that the number of eels—the 'eel-density,' so to say—decreases from the sea inland. In Canada, Ontario is the province farthest from the Atlantic where an eel-fishery is found. In the United States the eastern region, north of Florida, the rivers of which flow into the Atlantic, shows by far the greatest density, 98 per cent. of the eels caught in the United States; that of the central region, west of Florida, where the rivers open out into the Gulf of Mexico, being very much below, yielding only 2 per cent. of the whole capture.

The western region, which is drained into the Pacific, and in the main is lying west of the Rocky Mountains, is totally devoid of eels.

Very interesting are the results regarding the Great Lakes; here the eel-fishery of Lake Ontario far exceeds that of the other lakes. A glance at

the map gives us the explanation: Lake Ontario is nearest the sea from which the eels come, and in order to appear in the other lakes they must pass Niagara. The difficulties in doing that most probably are the main reasons for the decrease in number in the other lakes.

Of no less interest is the statement that eels fished in Wisconsin in fresh water connected with the Mississippi must have penetrated more than 1000 miles from the mouth of this river. Thus, eels can travel enormous distances even after they have entered the fresh water.

We may return now to the question of the centre of production of the American eel. I have proved that the propagation of *Anguilla vulgaris* takes place in all the long stretch from the Færös to the west coast of Morocco, and have described how the fry from the spawning places west of the British Isles and France, during and after metamorphosis, move eastwards, and how the eel-stock of all North-Eastern Europe is recruited from here. It is evident that the migrations of the fry, favoured by the direction of the current and by the extraordinarily long duration of the pelagic life, may be of a very surprising length, as shown by the distance from the interior of the Baltic, or from the northernmost Norway to the 1000-mètre curve in the Atlantic west of Europe.

In the western part of the Atlantic we have to do with another but very closely related species, the *A. chrysypa*. We are not justified in presuming that its biological conditions are identical with those of the European species. But the facts at hand tend to show that they are very similar, and that the distribution must find a similar explanation.

While many hundreds of the larval stages of *A. vulgaris* have been taken over this large territory, only three larvæ of the American eel have up till now been found. One was taken at 38° 47′ 20″ N. lat., 72° 37′ W. long.; one at 38° 25′ N. lat., 72° 40′ W. long.; a third was found cast ashore on the Bermudas (September 1906). These three captures occurred just within, or near to, the region where the temperature in depths of 1000 m. is the highest in the whole western part of the Atlantic. It is certainly not due to chance that the larvæ are found just here. Most probably the centre of the spawning-places must lie about 35° N. lat. and 70° W. long. In assuming this to be the case, the distribution of the American eel to the West Indies, with Guiana, Mexico, and the United States offers no special peculiarities. More remarkable is its occurrence in Canada, Newfoundland, and Labrador, because the temperature in deep water outside the last-named countries is very low, only 2° to 3° in 1000 m. depth. But when we remember the facts established for the European eel and consider the currents, we may see that there is probably no place in the world where such conditions exist for an effective passive transportation of pelagic organisms by the help of the sea-currents as just off the coast of the United States and northwards: that is to say, from the supposed centre of reproduction to off Canada and Newfoundland. A current chart gives here a maximum speed of no less than forty to eighty miles per day, while the minimum speed is from ten to fifteen miles. Probably, therefore, the young eels are able to go further in this direction than they would otherwise be able to do. If we compare the distances with those we know to be accomplished by European eels, they are by no means greater. The great abundance of eels in New Brunswick, Nova Scotia, and Prince Edward Island agrees well with this statement.

We have also another method of testing the correctness of the suggested theory that the eel-stock of these northern lands is recruited from places much farther south. We may, as I have done for Europe, examine the time of ascent of the 'elvers' in the different places in the United States, Canada, etc. Although the information here is far from being as complete as those for the European eel, it is sufficient to prove that the appearance of the young eels in the fresh water occurs earlier in the year farther

south: that is to say, earlier in the places adjacent to the supposed spawning-place. (The time of appearance extends, as in Europe, over a period of several months; in this region from the earliest spring to the autumn, but somewhat later in the year in Europe.)

Besides, the assumed situation of the spawning-centre agrees pretty well with the 'density of eels' observed in the United States. As we have seen, the eastern region, north of Florida, yields about 98 per cent. of the whole eel-production of the States. And of the eastern region, again, the part between Cape Hatteras and Cape Cod—a distance of only about 450 miles—yields by far the greatest portion. This part is situated only a little more to the north than the region where the warmest water is to be found in the depth.

It is well known that the transplantation of several fresh-water fishes to foreign countries, where they formerly were not found, has often been attended with great success. American trout are transplanted to Europe, the salmon to Australia, etc. Also eels, and young eels, have long ago been transplanted successfully, and recently experiments in transferring young eels from the Bristol Channel to the Baltic have proved that these transplantations could be done on a much larger scale if the knowledge of the biological conditions of this fish be rightly used.

In the case of eels, we must be clear as to whether we intend the transplanted specimens *to breed* or only to *grow in size*. If we were to transplant young eels into the large rivers of South America or Western Africa, hoping that the eel would establish itself and multiply, we should certainly be disappointed. The utmost we might attain would be that these rivers proved to be suitable nurseries for the transplanted individuals. Transplanting experiments made in the United States on the Pacific Coast have been closely studied. Quite a number of transplanted fishes have become established, and by their fertility so numerous as to be of great importance for the fisheries—*e.g.*, the shad (*Clupea sapidissima*), striped bass (*Roccus lineatus*), various carps (*Cyprinus carpio* and varieties), various species of salmon, cat-fish (*Ameiurus sp.*), etc. But the introduction of the eel proved to be a failure. In the first years after the introduction, a few eels were taken now and then; some of them seemed to have grown very quickly, perhaps owing to the favourable localities chosen for the experiments. But after the course of a few years the end came, without any fry appearing to replace and increase the stock set out.

It may now be said beforehand that any repetition of these experiments will end in the same way, since whatever care is taken to procure the transplanted eels as favourable conditions as possible for their life and growth, no human power can obtain for them the conditions outside in the sea which they require for reproduction.

It is quite another matter naturally, to consider it advantageous to plant out in the Western States a number of eel fry, with a view to later 'gathering in' the *same* individuals when they are grown up, as is done at several places in Europe where the eel-fisheries are technically highly developed, or where the price for eels, sold in the living condition, is very high.

---

4. *On the Parallelism between the Nymphaline Genera Adelpha and Chlorippe. By* F. A. Dixey, *M.A., M.D.*

The two Central and South American genera, *Adelpha* and *Chlorippe*, present in many of their species a curious parallelism, several forms of the one genus bearing a striking resemblance to corresponding forms of the other. This is analogous with other instances, as of the Pierine genera *Mylothris* and *Phrissura* in Africa, where even the local races of the species of the one genus are closely followed in appearance by those of the other.

What is the explanation of these phenomena? The resemblances can scarcely be fortuitous, inasmuch as they are not confined to one or two species, but run through a long series of forms in each genus. Probability is much against a merely accidental resemblance under such circumstances as these. Nor is the suggestion of a common influence of geographical surroundings adequate, for the resemblances only apply to obvious features, not to points of minute structure. Again, specimens of both genera, widely differing in appearance, may be found living under the same geographical conditions. The resemblances can scarcely be, to use Professor Poulton's term, 'syncryptic'; for the upper surfaces of the wings, where the likeness is chiefly exhibited, are remarkably conspicuous. A certain amount of community in pattern may be due to affinity, but this will not explain the close correspondence between some species of the two genera, together with the wide divergence between others.

The only feasible explanation seems to be mimicry. This is supported by various considerations, especially by the local coincidence of the mutually assimilated forms. The mimicry may perhaps be Batesian, *Adelpha* supplying the models and *Chlorippe* the mimics; on the other hand, at least one species of the latter genus is known to be common, and therefore unlikely to be a mimic in the usually received sense. On the whole there is some reason to think that this is a case of the mutual approach of inedible forms, a conclusion, however, that needs to be tested by experiment and observation in the field.

---

5. *Histiology of the Eye of Pecten. By* W. J. Dakin.

---

6. *Coral Reefs. By* J. Stanley Gardiner, *F.R.S.*

Section E.—GEOGRAPHY.

President of the Section.—Colonel Sir Duncan Johnston, K.C.M.G., C.B., R.E., F.R.G.S.

THURSDAY, AUGUST 26.

The President delivered the following Address:—

It has been usual for Presidents of this Section to make some allusion in their addresses to the principal matters of geographical interest which have occurred during the preceding year, and I propose to follow this custom before proceeding with the rest of my address, which would hardly be complete without some allusion to the great geographical achievements of the past year.

I doubt if there has ever been a year in which more important additions to geographical knowledge have been made than those resulting from the journeys of Dr. Sven Hedin, Dr. Stein, and Lieut. Shackleton.

Dr. Sven Hedin's previous explorations had deservedly gained him such a high reputation as an explorer that it seemed almost impossible for him to increase it, yet his recent expedition in Tibet, extending over two years, has enhanced his already great reputation.

Refused permission to enter Tibet from India, he was not to be deterred. Travelling round to Leh and making that place his starting-point, he entered Tibet and traversed in various directions a considerable tract, previously unexplored, of that country, making a good reconnaissance survey of the country he passed through.

A large part of his journey was through a bleak and inhospitable region, where he encountered intense cold and very great privations. At one time he went for eighty-three days without meeting a living soul, and the cold and hardships were such that out of ninety-seven ponies and mules with which he started only six came through. Yet in the following year, in the depth of winter, Dr. Sven Hedin again traversed this terrible country. In doing so he ran imminent risk of starvation, as his last sheep was killed a considerable time before he got through to country where he could obtain fresh supplies.

Dr. Sven Hedin's tact and resource were as great as his fortitude and courage. He made friends wherever he went, and, although the Tibetan Government sent orders over and over again that he should be turned back, he succeeded in spending two years in exploring the country, maintaining the most friendly relations with the Government officials and others whom he met. Besides exploring and surveying a large tract of previously unexplored country, he investigated the sources of the Brahma-

putra, the Indus, and the Sutlej, and in the course of his journeys he accumulated a mass of geographical and other scientific information.

Next comes Dr. Stein's expedition to Chinese Turkestan, by which he has made a most noteworthy contribution to geographical knowledge and antiquarian research.

Dr. Stein, accompanied by that capable surveyor Rai Ram Singh, who was later on relieved by that equally skilful and energetic surveyor Rai Sahib Lal Singh, travelled from India viâ Chitral and Kashgar. He commenced survey work in the eastern part of the Mustagh-ata range, and carried it along the Kun Lun Mountains, skirting the southern side of the Takla Makan Desert and the Lob Nor Desert to Suchou and Kan-chou. He surveyed a large area of the mountainous region lying westward of Kan-chou, then crossing the desert from Anshi to Hami he returned north of the Tarim River, skirting the southern slopes of the Tian Shan range, to Kashgar. During this very long journey Dr. Stein came across the ancient frontier wall, built about the second century B.C. He traced it west of Suchou, till lost in the desert, for some 250 miles, and he made various incursions into and across the desert, making discoveries of the greatest antiquarian interest.

After his return to Kashgar he surveyed the last unexplored portion of the Kun Lun mountains and the country containing the sources of the Khotan or Yurungkash River, which proved to be flanked on the south by a magnificent range of snowy peaks rising to over 23,000 feet; thence passing the sources of the Keriya River he skirted the southern slopes of this snowy range and finished by connecting this survey with that to the north of this range. The privations and hardships undergone by Dr. Stein and his party were very great, and, just as he completed his last bit of survey, he was unfortunate enough to get his foot badly frost-bitten, and had to hasten to more civilised parts for medical treatment.

Dr. Stein, during his expedition, displayed all the best qualities of an explorer—enthusiasm, determination, skill, and tact. The modest account he has so far given us of his travels, which gives a mere outline of his work, shows that the geographical as well as the archæological results of his expedition are of the greatest value.

The last completed exploration I propose to mention is Lieut. Shackleton's great journey in the Antarctic Circle, which has raised him to a high position among the gallant explorers of the Polar regions.

Lieut. Shackleton personally arranged and supervised all arrangements for the expedition, his experience in the British Antarctic expedition under Capt. Scott standing him in good stead.

Having landed in McMurdo Sound, a party consisting of Lieut. Adams, Prof. David, and others ascended Mount Erebus, which is over 13,000 feet high, all above snow level.

Later on Lieut. Shackleton and a sledge-party set off southward, and after an arduous journey succeeded in reaching 88° 33′ south latitude, over six degrees nearer the Pole than any previous explorer. His party travelled altogether about 1700 miles, including relays, in 126 days, a splendid performance in a rough and difficult country under very trying climatic conditions. Soon after passing 83° 33′ south latitude they lost their last pony, and from this point they had to drag their sledges themselves, although their journey involved the ascent of a plateau 10,000 feet high. They only turned back when their diminishing stock of provisions rendered it imperatively necessary to do so. They were for a considerable time on short rations, and found several times that they had expended their food supplies before reaching their next depôt. Had they missed one of these depôts—no unlikely contingency in such a country—they must have perished by starvation. Altogether the sledge journey was a great feat of pluck and endurance.

Lastly, Lieut. Shackleton's colleague, Prof. David, with others, made a sledge journey to the north-west, reaching the South Magnetic Pole. A good deal of triangulation was carried out, many geological specimens were collected, and much scientific information was obtained.

Whether we consider Lieut. Shackleton's skill and energy in organising the expedition, the courage and determination displayed in carrying it out, or the results obtained, his expedition will stand out as one of the greatest of the many great efforts to reach the Poles, and as a British expedition it is one that specially appeals to us.

At first sight it would seem that these great journeys belie the opinion so often expressed of late years that the days of the explorer are numbered, and that in future geographers will have to deal with surveys rather than exploration; but, in fact, these splendid achievements only strengthen this opinion. These explorers have considerably reduced the comparatively small area still unexplored, and other expeditions are helping to diminish the unexplored area.

Among those which are in progress I may mention the following:—Col. Kozlof's expedition to Mongolia, which has already visited Kuku Nor and which is exploring the upper course of the Huang Ho and other parts of Mongolia. Lieut. Boyd Alexander is exploring in West Africa. The Duke of the Abruzzi is investigating part of the mountainous region across our Indian frontier; Dr. Longstaff is exploring another part of that mountain system; Capt. R. E. Peary, U.S.A., and Capt. E. Mikkelsen are leading expeditions in different parts of the Arctic regions, and M. Charcot is exploring in the Antarctic Circle. Lastly, an important British expedition will start before long to explore part of the Island of New Guinea, one of the largest still unexplored land areas. There are other expeditions, either in progress or projected, too numerous to mention.

The best modern explorers are not now content with exploration or even with a rough route traverse and an occasional observation for latitude; they either themselves make careful reconnaissance surveys of the country adjoining their route or they are accompanied by trained surveyors, who make such surveys.

Again, every year the area surveyed on correct scientific principles is extended. The interesting address of my predecessor, Major Hills, will have told you what is being done in this way in the British Crown colonies. In the British self-governing colonies and in the colonies and dependencies of other Powers the area of regular survey is being continually extended, and in more remote regions surveys are being carried out by Boundary Commissions or for railways or other purposes. Along with the increasing appreciation of the value of geography which has taken place of late years, there has been an increasing recognition of the need for regular surveys, and it is probable that the next generation will find that not only is no considerable area of the earth's surface unexplored, but that the area not yet surveyed at least geographically, or for which a regular survey has not been projected, is getting limited.

I propose in the rest of my address to deal with the regular survey and mapping of new areas, and to discuss various questions connected therewith; if I am right in believing that large areas will be regularly surveyed in the near future, such questions merit careful consideration. I shall state on these points the practice of some of the great national surveys, because their experience seems the best guide for future work; but I recognise that methods suitable for rich and populous countries, such as Germany, France, or Great Britain, may be too costly for many countries and provinces whose survey has still to be made, and mention will be made of less expensive methods which are likely to be much in demand in future.

It would be difficult to say anything new on the subject I propose to deal with, and I lay no claim to do so, still less do I wish to dogmatise as to the best methods. When I express opinions I shall also state the practice of some of the principal surveys of the world, and my hearers having weighed the matter can accept my opinions or not according to their judgment. In either case my object will have been attained if careful consideration is given to the points raised.

Maps may be roughly divided into three classes:—

(1) Geographical maps—*i.e.*, those on very small scales.

(2) Topographical maps. The dividing line between these and geographical maps is not very clearly defined. For the purpose of this address maps between the scales of four miles to the inch and $\frac{1}{25000}$ scale will be considered as topographical.

(3) Cadastral maps—*i.e.*, maps on large scales mainly for property purposes.

As the time at my disposal will not admit of my discussing all three classes of maps, and as I have on a previous occasion read a paper to this Association on 'Cadastral Surveying,' I propose to limit my remarks to topographical surveys and maps.

In most of the older countries topographical surveys have originally been made to meet military needs, and as a rule they are carried out under military supervision. In order that they may be useful in case of war such surveys must have been made before war breaks out. The use, however, of topographical maps is not limited to military purposes; on the contrary, they have invariably proved of great value for civil requirements. In one respect they are more useful for civil than for military purposes, as a state of war occurs rarely, and hence while the maps are only occasionally used in connection with war, they are constantly used in connection with civil administration and with public and private business of all kinds. The topographical maps of the Ordnance Survey, prepared originally solely for military requirements, have proved extremely useful for civil purposes. Directly or indirectly all the numerous maps prepared by the trade in Great Britain for civil use are based on them. I believe the experience of all other countries is similar to that of the Ordnance Survey. In most countries in which land is of any value, a cadastral survey for land transfer purposes is needed, as well as a topographical survey. In some cases indeed, the need for a property survey has first made itself felt; thus in the Transvaal and in the Cape Colony, neither of which yet has a topographical survey, there has for many years been a Government Survey Department for making property surveys. The question arises whether there should be two separate surveys, one for topographical and one for cadastral maps, or whether there should be only one survey, the topographical maps being prepared by reducing the cadastral survey. Incidentally the further question arises whether, if two separate surveys are made, they should be under one head.

In most countries—the Ordnance Survey of the United Kingdom being an exception—not only are entirely separate surveys made for these two classes of maps, but these surveys are generally under different departments. In some cases the cadastral surveys are isolated farm surveys, showing little detail except property boundaries. Such surveys would, of course, not answer as a basis for topographical maps. In other cases, however, the cadastral surveys show all necessary detail except ground forms, which can be added by a separate survey. The only cadastral survey, so far as I know, which shows ground forms is the Ordnance Survey, whose 6-inch maps are contoured.

A difficulty in the way of utilising the cadastral survey for the smaller scale maps arises from the fact that a cadastral survey is, from its

large size, much slower than a topographical survey. It is often found advisable to take up the survey of the former somewhat irregularly, while it is important for the proper progress of the latter that it should be taken up regularly and methodically. The Ordnance Survey 1-inch map has, since 1824, not had a separate survey of its own, but has been based on the cadastral survey. Ordnance Survey experience has shown that the delays in completing the topographical map, due to this course, have been much greater than one would have expected, and that there are grave disadvantages in having the scale of survey very much larger than that of the finished map. These objections do not apply, or can be overcome, if the cadastral survey of any locality is completed before the topographical map is taken up. This is a condition not likely to be often fulfilled in the case of future topographical surveys. I advocate therefore that, following the general practice, there should be entirely separate topographical and cadastral surveys. I should advocate this even where it is essential to keep the expense as low as possible. More economy would probably result from the adoption of a fairly small scale for the topographical map, from curtailing the small detail to be shown on it, and from showing on the cadastral maps only such detail as is needed for property purposes, than would result from making one survey do for both classes of maps.

On the other hand I consider that, even when separate surveys are made for the two classes of maps, it is advantageous that both should be made under the same head. The more usual course is, however, to have the two surveys independent, and in some cases local circumstances may make the course I advocate inadvisable.

Triangulation.

The first preliminary to any survey should be a triangulation. It is the most satisfactory course, and the best economy in the long run, to carry out with the greatest accuracy possible the primary triangulation on which the survey is to be based. Such a triangulation will remain good for a very long period. For example, the primary triangulation of the Ordnance Survey was commenced in 1791; while some doubts have been expressed whether it is accurate enough to combine with other more recent work for the purpose of investigating the figure of the earth, no one has questioned that even the earliest part of this triangulation is amply accurate enough for map-making purposes.

On the other hand I do not advocate carrying out a primary triangulation until arrangements have been made for basing a survey on it. In South Africa an excellent and very accurate primary triangulation has been carried out. This triangulation was undertaken largely no doubt for scientific purposes. While answering its purpose in that respect it has so far had no surveys of any great extent based on it. An accurate triangulation is now a much quicker and less expensive operation than it used to be. The introduction of Invar tapes and wires has largely expedited and simplified the accurate measurement of base lines, while the improvements effected in theodolites enable equal or greater accuracy to be obtained with the comparatively small and handy instruments now made than could be got formerly with large and cumbrous instruments, such as the 36-inch theodolites, with which most of the primary triangulation of Great Britain and Ireland was carried out. Unless observations are rendered difficult by numerous buildings, by trees or by a hazy or smoky atmosphere, a good primary triangulation should not now be very expensive. It is usual to base on the primary triangulation a minor triangulation of several orders, the object being to have an accurate framework of trigonometrical points on which to base the survey. If it is important to keep the expense low, the trigonometrical points may be rather far apart, intermediate points being fixed by

plane table; but it should be remembered that it is the truest economy to make the best triangulation which funds admit of. In forests or in wooded and rather flat country, where triangulation would be very expensive, lines of traverse made with every possible accuracy, and starting and closing on trigonometrical points, may be used instead of minor triangulation.

Detail Survey.

Provided the detail survey is based on triangulation, it may be made by any recognised method. Plane tabling is now almost universally resorted to, and is probably as cheap and convenient as any other method. The vertical heights of the trigonometrical points will have been fixed by vertical angles with reference to some datum. The height of intermediate points can be fixed by clinometer lines, especially down spurs and valleys, and even by aneroid, and from these heights the contour lines can be sketched in. Altitudes can be more accurately fixed by spirit-levelling, but this is an expensive method not likely to be much used in the case of topographical surveys. It is possible that in exceptional cases photographic surveying may be resorted to with advantage, and undoubtedly photographic methods sometimes enable work to be done which would not otherwise be feasible. The photographic method suggested by Captain F. V. Thompson, R.E., is an advance on previous methods. In Canada, I understand that a good deal of photographic surveying has been done, and presumably the conditions in Canada have been found suitable for this method. It has been little used elsewhere.

Scale of Map.

The next point for consideration is the scale on which the map is to be published, and it is an important one. Speaking generally, the cost increases with the scale, and cost is therefore one of the main determining considerations. The physical and artificial character of the country, the amount of detail it may be decided to show on the map, the method adopted for representing hills and other detail, and the method of reproduction to be used, all affect the question.

Clearness and legibility are among the first essentials of a good map, and it is desirable that the scale should be such that all detail it may be decided to show on the map can be inserted without overcrowding, or conversely, if the scale is fixed, the amount of detail and method of showing it should be such as to avoid the common fault of overcrowding the map.

In populous countries, such as Belgium, France, and Germany, where buildings, roads, railways, &c., are numerous, a larger scale is, *cœteris paribus*, desirable, than in less populous countries.

All important detail such as roads, railways, canals, forests, woods, etc., should appear on the map, as should the more important names, but it is a matter for consideration how far minor detail such as orchards, marshes, rough pasture, state of cultivation, &c., should be inserted on the map, and to what extent the less important names should be omitted.

In hilly country hachures and contours, especially if in black, tend to obscure the detail and names, and the smaller the scale the greater this tendency.

Methods of reproduction will be dealt with later, but I may here say that more detail and names can be shown clearly on a given scale if the map is engraved on copper than if reproduced in any other way. The scales adopted by different countries vary very much—I give below the scales adopted by some of the principal surveys.

$\frac{1}{25000}$ scale—Switzerland (the more populous parts), Prussia, Baden, Saxony, Bavaria, and Würtemberg (these German maps, although called maps of position, are practically topographical).

$\frac{1}{40000}$ scale—Belgium and Denmark.

$\frac{1}{50000}$ scale—France (the new topographical map), Algeria, Tunis, Holland, Japan, Spain, Switzerland (the less populous parts).

$\frac{1}{62500}$ scale—the United States (the more populous parts).

$\frac{1}{63360}$ scale (1 inch to a mile)—Great Britain and Ireland, and Canada.

$\frac{1}{75000}$ scale—the Austrian Empire.

$\frac{1}{80000}$ scale—the old staff map of France.

$\frac{1}{100000}$ scale—the German Empire, Italy, Norway, Portugal, Sweden, and Switzerland (Dufour atlas).

$\frac{1}{125000}$ scale—the United States (the less populous parts).

$\frac{1}{126000}$ scale—Russia.

$\frac{1}{250000}$ scale—the United States (barren districts).

The introduction of cycles, motors, and other rapid means of locomotion has led to a demand for a scale which will show a considerable tract of country on a sheet of moderate size. If the standard map is already on rather a large scale, this demand is best met by publishing a reduction of the standard map. This course is followed by Great Britain and Ireland and by Canada, whose 1-inch map is reduced to and published on the $\frac{1}{2}$-inch scale; but if only one scale is used a compromise must be arrived at which will meet the reasonable requirements of rapid locomotion, as well as the other essentials of a topographical map.

If I may venture an opinion in a matter in which practice varies so much, it is that for countries using British measures in which, owing to dense population, the detail is close the 1-inch scale ($\frac{1}{63360}$) is a very good one, and that for more open parts the $\frac{1}{2}$-inch scale may with advantage be adopted. For countries using metrical measures I should advocate $\frac{1}{62500}$ and $\frac{1}{125000}$ respectively. These scales do not differ largely from those adopted by most of the principal countries, the majority of whom use scales between $\frac{1}{50000}$ and $\frac{1}{100000}$ for fairly close countries.

Where it is important to keep the cost down I should advocate a half-inch to the mile or a $\frac{1}{125000}$ scale. All except the most closely populated country can be shown clearly on such scales provided the maps do not show too many names or too much small detail.

The United States have scales of $\frac{1}{62500}$, $\frac{1}{125000}$, and $\frac{1}{250000}$, the general closeness of detail in any area determining which of these three scales is adopted. This arrangement is a good one, and would be still better if the areas published on the $\frac{1}{62500}$ scale were also reduced to and published on the $\frac{1}{125000}$ scale, and if the whole country were published on the $\frac{1}{250000}$ scale. The principle here advocated of having each scale as far as possible complete for the whole country has been carried out by Great Britain, where the whole country, except some uncultivated areas, is published on the 25-inch ($\frac{1}{2500}$) scale, and the whole country on the 6-inch, the 1-inch, the $\frac{1}{2}$-inch, the $\frac{1}{4}$-inch, and other smaller scales.

Scale of Field Survey.

It is usual to make the field survey for small scale maps on a larger scale than that on which the map is to be published with a view to securing greater accuracy of detail, but this should not be overdone. If the field survey is on too large a scale it entails needless expense, also when the surveyor is working on too large a scale he is apt not to realise the effect of reduction on his survey, and is likely to survey so much detail as to overcrowd the map, thus increasing the cost of the work and injuring the map.

When the map is reproduced by photographic methods the fair drawing is usually on a larger scale than the finished map, so as to get finer results on reduction; but in this case also, for somewhat similar reasons to those stated

above, there are limits to the amount of reduction which can be made with advantage.

In these respects the practice of different countries varies considerably.

In Austria the field survey is on the $\frac{1}{25000}$ scale; this is reduced to and drawn on the $\frac{1}{60000}$ scale, and this drawing is reproduced by heliogravure on the $\frac{1}{75000}$ scale.

In France the field survey is on the $\frac{1}{10000}$ or $\frac{1}{20000}$ scale. The survey is reduced to and drawn on the $\frac{1}{40000}$ scale. In Algeria and Tunis, both field survey and drawing are on the $\frac{1}{40000}$ scale. In all cases the French maps are now reproduced by heliogravure on the $\frac{1}{50000}$ scale from the $\frac{1}{40000}$ scale drawings.

In Germany the field survey is on the $\frac{1}{25000}$ scale. This is reduced to the $\frac{1}{100000}$, on which scale the maps are engraved on copper.

In Great Britain the 1-inch map is based on the 25-inch and 6-inch survey. These were reduced, and a fair drawing was made on the 2-inch scale in a manner suitable for reduction to the 1-inch scale—*i.e.*, the detail, lettering, etc., were drawn so that when reduced to the 1-inch scale they should be in proper proportion. This drawing was reduced and printed by heliozincography on the 1-inch scale, and from these prints was engraved on copper.

In America the field surveys are on the scales of $\frac{1}{48000}$, $\frac{1}{96000}$, and $\frac{1}{192000}$ for the $\frac{1}{62500}$, the $\frac{1}{125000}$, and the $\frac{1}{250000}$ scale maps respectively. The drawings, on the same scale as the field survey, are reduced by photography and engraved on copper.

I consider that the best results are obtained when the field survey is made on double the scale of the finished map; that if reproduction is to be by engraving, the fair drawing should be on the same scale as the finished map; that if, on the other hand, reproduction is to be by photographic methods, the fair drawing should be on the same scale as the survey, *i.e.*, double that of the finished map. The reduction I advocate should conduce to accuracy of detail and, if reproduced photographically, to fineness of detail, while it is not so great that the surveyor and draughtsman should be unable to realise the effect of reduction.

Detail.

The need of considering the amount of detail, &c., to be shown is not always sufficiently realised. The way in which detail is to be represented also needs consideration, as on small scale maps much detail has to be represented conventionally.

Railways have to be shown conventionally, and should be so marked that they catch the eye without being too heavy.

Roads also should be clearly marked. Where different classes of roads exist they should be distinctively shown, main roads being more prominent than others. It is important to know what roads are fit for fast wheeled traffic in all weathers, and which are fit only for slow traffic. The exact classification of roads must depend on the conditions obtaining in the country. The most elaborate classification is that shown on the French maps, and next that shown on the maps of Great Britain. Provided that important distinctions are represented, the simpler the classification the better.

Forests, woods, marshes, and in some cases pasture, rough pasture, orchards, vineyards, gardens, etc., are shown by conventional signs. While forests, woods, and marshes should certainly be distinguished on the maps, I incline to the opinion that the state of cultivation is better omitted, and that the less small detail shown the better. Such small detail increases the cost and often overcrowds the map. The German $\frac{1}{100000}$ scale shows much small detail, and although the maps are beautifully and delicately

engraved on copper, the detail is rather crowded on some sheets. The French Carte Vicinale is, in my opinion, rather crowded with names.

The most difficult question, and that on which opinions differ most, is the method of representing ground forms. Methods which answer well on steep ground are less satisfactory on gentle slopes, and *vice versâ*, and each method is open to some objection.

Ground forms may be indicated by contours, hill shading in stipple, vertical hachures, horizontal hachures, the layer system, or by a combination of some of these.

Ground forms are represented by contours on the $\frac{1}{25000}$-scale maps of the German States, the Swiss Siegfried Atlas, the maps of the United States, the 1-inch map of Canada, the $\frac{1}{40000}$-scale map of Denmark, and the maps of Japan. Where the slopes are steep the contours give almost the effect of hill-shading. Some of these maps give a very good representation of the ground, the best being those in which the contours are in colour.

Hill features are shown by stipple shading on the French Carte Vicinale and the Ordnance Survey four-mile map. In mountainous country stipple shading gives a good pictorial representation of the ground, but it fails in flatter country, and it is often difficult to tell from it which way slopes run.

The Swiss Dufour Atlas ($\frac{1}{100000}$ scale) is a good example of vertical hachuring, as are some of the German $\frac{1}{100000}$-scale maps. Vertical hachures are also used on the Austrian and Swedish maps, and in conjunction with contours on the maps of several other countries.

Vertical hachures when well executed give an artistic and graphic representation of the hills. In the Swiss and British maps the pictorial effect is enhanced by assuming a light from the left-hand top corner. In steep ground, especially when the hachures are in black, these are apt to obscure detail and names. I think hachures are better when printed in colour, but many will disagree with me on this point.

Horizontal hachuring, while having some advantages, is less effective and is little used.

The system generally known as the layer system has been used in Great Britain by the well-known Scotch firm of J. Bartholomew & Co., has recently been adopted by the Ordnance Survey for its $\frac{1}{2}$-inch maps, and is used in the $\frac{1}{2}$-inch maps of Canada. It consists in indicating by various shades of colour the area lying between certain contours; thus one shade may be given to all ground below the 50-foot contour, another shade to ground between the 50 and 100 foot contour, and so on. This system gives a general indication of ground form and enables the contour lines to be followed more easily. Its shades of colour enable the eye to pick out more easily all land lying at about the same level. It is most effective in ground with a small range of vertical height, as the vertical depth of layers can then be small and the distinction in colour between successive layers marked. In hilly ground the depth of the layer must be increased, which means that many ground features are ignored on the map, or the number of layers on the map must be large, in which case the distinction in shade between successive layers will be less marked. This method is popular in Great Britain, and enables those who are not versed in reading contours and hachures to realise something of the nature of the ground forms.

A combination of these methods has been used as follows:—

France on her $\frac{1}{50000}$-scale maps shows ground forms by contour lines and stipple shading. This gives a very fair representation of the ground, but where the contours are very close together the effect of the coloured contours on the stipple is not pleasant. Nor does the stipple always look well when it falls on colour.

The German coloured $\frac{1}{100000}$-scale map, the Italian $\frac{1}{100000}$, and the British 1-inch show both contours and vertical hachures.

The Norwegian $\frac{1}{100000}$-scale map shows the features by contours, vertical hachures and shading.

The new British $\frac{1}{2}$-inch scale map has both contours, layers and stipple shading.

Opinions differ so much on this subject, and there is so much to be said for and against each method, that I will confine myself to the opinion that contours reasonably close together should form the principal feature of any method of representing ground forms; that contours by themselves give a very fair representation of the ground; that vertical hachures, if printed so as not to obscure the detail and names, or stipple shading when there is not too much colour on the maps, increase the pictorial effect and are useful additions to contours; that ground forms should preferably be in colour, and that where hachures or stipple are used as well as contours both should be in the same colour.

The German coloured $\frac{1}{100000}$-scale map (brown hachures and contours), the British 1-inch scale copper-plate printed map (brown hachures and black contours), the British 1-inch coloured map (brown hachures and red contours), and the French $\frac{1}{50000}$-scale (grey stipple and brown contours), all give a good representation of the ground, and there are other maps which might be named almost, if not quite, as good.

Vertical Interval of Contours.

The vertical interval between contours should depend partly on the scale, partly on the steepness of the ground. Practice varies considerably in this matter.

The $\frac{1}{25000}$-scale maps of Switzerland and of Germany, except Prussia, are contoured at 10-mètre intervals.

The $\frac{1}{50000}$-scale maps of France are contoured at 10-mètre intervals.

The $\frac{1}{50000}$-scale maps of Japan and Spain are contoured at 20-mètre intervals.

On the Swiss $\frac{1}{50000}$ scale contours are 30 mètres apart.

On the United States $\frac{1}{62500}$ scale the contour interval varies from 20 to 100 feet.

On the British 1-inch map there are contours at 50 feet, at every 100 feet up to 1000 feet, and thence at 250 feet intervals.

On the Canadian 1-inch and $\frac{1}{2}$-inch maps the contour interval is only 25 feet, but the sheets published have been in ground with only moderate elevations.

On the German $\frac{1}{100000}$-foot the contour interval is 50 mètres.

I consider that if the contours are printed in colour the vertical interval may with advantage be such that on steep ground the contours are reasonably close together, every fourth or fifth contour being printed heavier so as to be more easily followed. If the contours are in black they cannot with advantage be so close.

It is, in my opinion, best if the contour interval is uniform all over a country. Failing this, it seems desirable that it should be uniform over considerable areas and at least throughout a sheet; but this view is not universally held. I do not like the varying interval adopted by the Ordnance Survey. The contours on the Ordnance Survey maps are surveyed with great accuracy and at great expense. For topographical maps much cheaper and more rapid methods will suffice.

Cartography.

I have, with a view to clearness, kept the question of the method of reproduction separate, but it has a bearing on some of the points already considered. Thus the fine engraving of the German $\frac{1}{100000}$-scale map enables an amount of small detail and ornament to be shown on that map which

could not have been clearly shown if any other method of reproduction had been used.

The older maps were generally engraved on copper, or sometimes on stone, and printed in black and white. Subsequently photographic methods, such as the photogravure of the Austrian and the more recent $\frac{1}{50000}$-scale French maps, were used, and colour printing is now largely resorted to.

In some cases the colour-plates are prepared by engraving on copper, stone, or zinc. The maps of the United States and Switzerland are engraved on copper. In other cases, for instance, the 1-inch Ordnance Survey, colour-plates are prepared on stone by transfers and offsets from the engraved copper plate. In other cases—*e.g.*, the $\frac{1}{50000}$-scale map of France—the colour-plates are prepared by photographic methods.

For clearness, delicacy of outline, and artistic effect nothing equals engraving on copper. It forms also the best basis for colour-printing. Unfortunately it is very slow and costly.

Engraving on stone is quicker and less expensive than copper engraving. It is inferior in delicacy to the latter, but some of the best stone engraving is very good.

Photographic methods are the most rapid and the cheapest, and with care give very fair results. As good examples I may quote the $\frac{1}{75000}$-scale maps of Austria, prepared by heliogravure, and the 6-inch maps of the Ordnance Survey, prepared by heliozincography, both black and white maps.

Of colour-printed maps I may instance the new $\frac{1}{50000}$-scale map of France prepared by heliogravure, and the $\frac{1}{2}$-inch Ordnance Survey map hitherto prepared by photo-etching, although I understand that in future the outline will be engraved on copper.

When rapid reproduction and moderate cost are desired I do not hesitate to recommend photographic methods which, although not so good as engraving, give, when carefully executed, reasonably good results.

Opinions differ as to the extent to which colour should be used, the modern tendency being to use it very freely. I can hardly be accused of prejudice against colour, as during my tenure of office at the Ordnance Survey colour-printing was largely developed, but I think it is often overdone. I consider that a moderate amount of colour is a great improvement to a map. Ground forms, however indicated, can, in my opinion, be better shown by colour than in black; it is advantageous also to distinguish water by colour, to give prominence to main roads by colouring them, and to colour woods and forests, but I do not advocate going much beyond this. It is difficult to choose colours which are suitable, distinctive, and harmonious, and the more numerous the colours used the greater the difficulty of doing so.

Colour-printing introduces possible sources of error. Colour maps are based on a drawing on which all detail to appear on the map is shown. A plate is prepared for each colour on which there should be only such detail as shall be printed in its particular colour. In preparing this plate there is a risk that detail which should appear may be omitted, or that detail be inserted which should be on another plate, or that the detail may be slightly out of position. Again, owing to change of temperature and to the varying amount of moisture in the air, paper contracts or expands. Registration can rarely be mathematically correct, and with every care may sometimes be appreciably out. While with care errors such as I have indicated can be minimised so as not appreciably to affect the map, it is difficult to ensure that they should be altogther absent.

To recapitulate my views, I advocate for a topographical map a scale between $\frac{1}{62500}$ and $\frac{1}{126720}$ ($\frac{1}{2}$ inch to a mile), according to circumstances. The scale of survey to be double that of the finished map; ground forms to be shown by contours reasonably close together, the exact interval depending on the scale of the map and the nature of the country, also, if

funds are available, by vertical hachures; both contours and hachures, if shown, to be in colour, the same colour being used for both. If considerations of time and cost do not admit of reproduction by engraving on copper, the map to be reproduced by some photographic method and printed in not more than five colours. I put forward these opinions rather as a basis for consideration than as having special weight in themselves. With the increasing recognition of the importance of geography an increasing demand for maps is sure to come, and good maps can only be satisfactorily designed after considering the points here discussed.

It is not yet, I think, generally recognised that a really good topographical map, based on triangulation, may be produced on a scale of about ½ inch to the mile at very moderate expense if unimportant detail is left out and survey and reproduction carried out as economically as possible. Such a survey has recently been carried out in the Orange River Colony, a country mainly agricultural with generally poor land. There must be few parts, other than barren and mountainous regions, under settled government where such a survey would not be of value. I believe that in future still further economy in surveying and mapping will be attained, and this will stimulate the undertaking of fresh surveys.

Meeting, as we are privileged to do this year, in Canada, I should like to say a few words on the surveying and mapping of the Dominion. Until recently the only maps published have been on very small scales and have shown no ground forms. During the last few years, however, a regular topographical survey has been undertaken by the Militia Department. I am glad that for this topographical survey the scales of 1 inch and ½ inch to the mile, both standard scales in Great Britain and Ireland, have been adopted. They are, in my opinion, suitable scales for Canada, and it is to be hoped that for any new mapping within the British Empire these or similar scales may be adopted as they have been in many parts. Uniformity in scales is very desirable.

Without committing myself to praise in every respect of the maps prepared by the Militia Department, I may say that they appear to me excellent, well-executed maps. Not many sheets have yet been issued, and they are probably not yet well known even in Canada; but I have little doubt that when known their value will be appreciated, and that the area mapped will be rapidly extended. There are no doubt large areas in Canada for which a smaller scale than one inch will suffice, but there can be few, except waste and barren regions, for which maps on some scale will not be needed. To a country like Canada, which has made wonderful progress already, and which has a great future before it, adequate mapping must be of importance, specially so in view of the vast area of the country. I have misread the character of the Canadian people if they will be content with any except first-rate maps for the whole settled area of the Dominion.

I should like to have said a few words on the aid which good maps give to geographical education, but my address is already too long. I will only say that while good maps and geographical education are of use to all countries, they are of special value to the British Empire, whose different parts are geographically so scattered, but which are so closely bound together by common ties of kinship, interest, sentiment, and loyalty.

The following Papers were then read:—

1. *Floods in the Great Interior Valley of America.* *By Miss* L. A. Owen.

The conditions which produce floods, the diversified character of their inevitable consequences, and the possibility of future control, either with or

without attendant evils more disastrous than the floods themselves, afford one of the most complex and vital series of questions with which the American nation has yet been engaged.

Although mountain snow-fall and local rains are the obvious causes of flood conditions, both may be excessive without producing such results. Observations show that many combinations of circumstances which tend to hasten or retard the outflow of headwaters give rise to a varied series of highly interesting and far-reaching effects, either involving the low-lands of the entire valley country between the east and west mountain ranges in a brief but destructive deluge, or distributing local floods over widely separated districts, or yet again by the slower process of run-off, showing how the heaviest precipitation may be carried to the Gulf of Mexico with no accusing record of overflow disaster.

Consequences peculiar to the various conditions must inevitably develop in corresponding ratio of extent and importance, which raises the problem of control to a position of magnitude second to no other, and involving serious future dangers as well as magnificent benefits.

---

2. *The Nomenclature of the Islands and Lands of Arctic Canada.*
By JAMES WHITE.

---

3. *The Hudson Bay Route to Europe.*
By ROBERT BELL, *I.S.O., M.D., F.R.S.*

The author emphasised the advantages of this route and the important economic results which would follow its development. It was by far the shortest possible route from the centre of the prairie provinces, as its general course was that of a segment of a great circle. The proportion of land-haul was shorter than that of any other route. More than 1,000 miles of its water transportation is within the British possessions, Hudson Bay being a *mare clausum.*

Heretofore various circumstances had tended to prejudice the public against this route. An effort had been made to associate the bay with the Arctic regions, and to make the public believe that the season for navigation was too short, and that floe ice would be a more serious obstacle than it really is. It is, however, true that in the days of sailing ships even small quantities of loose ice did sometimes interrupt their progress, but steam navigation has changed all that and put an entirely new aspect on the problem. The writer had passed through the strait nine different times, and did not think that the ice would seriously impede its navigation by ordinary steamships. It was to be regretted that so much nonsense had been talked and written by persons who had no independent knowledge of this subject.

The delay in attempting to open up the route had been due to questions of public expedience, and not to any actual or known natural obstacles. The writer had for more than thirty years advocated the opening of this route at the earliest possible time as being of the greatest importance to the development of the trade and populating of the Canadian North-West. The immediate increase in the value of the wheat lands alone, as soon as a railway is constructed to the bay, would amount to about $100,000,000. Live stock, dairy products, coarse grains, and several kinds of other agricultural products could then be profitably exported, and their value would perhaps more than equal that of the wheat.

The building of a railway to Hudson Bay has only now become a living question on account of the existing railways being inadequate to transport all the outgoing freight offering. As soon as a Hudson Bay railway is in

operation it will naturally bring in a large share of the imports, as well as of the passenger traffic.

In former years, although the population of Manitoba and the North-West Territories was small, there was a constant demand for the consideration of the Hudson Bay route by the Canadian Government. This was appeased and time gained by sending out expeditions by sea in 1884-85-86 and 1897. The writer accompanied all of these expeditions, except one, as naturalist and geologist, and on two of them he also acted as medical officer.

The expedition of 1884, by the steamship *Neptune*, carried out six parties to occupy three stations on the north and three on the south side of Hudson Strait, for the purpose of making meteorological observations for one year. In the following year six fresh parties were sent out by the steamship *Alert*, to replace those of the previous year, who were brought home; and in 1886 the *Alert* returned to the strait and brought back the second group of parties, together with all the station buildings except those on Big Island, midway up the north side of the strait. Instead of allowing each of the twelve officers who had been in charge of these stations to write a report on his observations, and to state his conclusions or opinions, only a general report by the commander was published for each of the two years. Neither of these reports showed that there was any real difficulty in navigating the strait or the bay.

The mouth of the Churchill River, which is surrounded by solid rock, offers the best natural harbour on the west side of Hudson Bay; but, as the course of this river lies in a northern region, it is a clear cold-water stream, and freezes over earlier than the Nelson River, which is a white stream, and brings down to the sea the warm water of the lakes of the Manitoba basin, which are of more southern origin, and they retain much of their heat and do not freeze till December, thus giving an open season of seven months. If an artificial harbour could be constructed in the mouth of the Nelson, it might enable navigation to be maintained to the west side of Hudson Bay during a longer season than to Montreal. Beginning with 1875, the writer has had much personal experience in and around Hudson Bay and Strait, and he is sanguine that a successful transportation business can be carried on between the interior of North America and any of the seaports of the world by way of Hudson Bay.

Joint Meeting with Section F and Sub-Section K (Agriculture).

FRIDAY, AUGUST 27.

The following Papers were read:—

1. *The Economic Geography of Canada. By* Professor James Mayor.

The author described the relation of the hydrographical system of Canada to its early development, and contrasted the river and lake system of America with those of Europe—the former consisting of rapid streams rising at high levels, and sometimes obstructed by rapids or falls due to sharp changes of level, while the latter consists, for the most part, of sluggish streams, sometimes forming networks which are readily navigable for great distances by small or large vessels. The earlier and more rapid colonisation of the European area is thus accounted for, while the earlier penetration into the interior plains of America was accomplished by means of the rivers. The contours and country are such as to render extensive immigration by means

of them under primitive conditions impossible; the colonisation of America had thus to wait for the development of mechanical means of transportation upon land.

The chief economic fact in the history of the American continent is the railway development as a means of colonisation.

The author described in general terms the situation of the more important natural resources, and gave a brief account of the localities of different industries.

---

2. *The Seychelles. By* J. Stanley Gardiner, *F.R.S.*—*See Fourth Report on Investigations in the Indian Ocean*, p. 198.

---

3. *The Cycle of Alpine Glaciation.* *By* Professor William Herbert Hobbs.

Though differing widely in the nature of the erosional process and resulting in forms of wholly different aspect, there may be recognised in the sculpturing of upland regions by rolling glaciers a differentiation into stages analogous in some respects to those well determined for river erosion. Studies lately completed in many mountain districts once occupied by glaciers of the Alpine type, and the new and much-improved topographic maps, permit of new generalisation concerning relative degrees of maturity and the natural limitation of the cycle.

---

4. *The Formation of Arroyos in Adobe-filled Valleys in the South-Western United States. By* Professor Richard E. Dodge.

Many of the valleys in Arizona, New Mexico, and other arid regions in the United States are partially filled with a compact clay of probable sub-aerial origin, known as adobe. Such valleys usually have a longitudinal slope of not more than five degrees and a cross slope of somewhat more than five degrees. Many of these filled valleys are now being actively dissected and longitudinal arroyos from 20-50 feet in depth have been cut. These arroyos have few side branches and are being extended headwards mainly. The arroyos are evidently of recent origin, and a comparison of the accounts made by early expeditions in the Chaco Valley shows a rapid increase in length since the first reconnaissance surveys in the region.

Evidence from the study of sections and peoples is strong that formerly the valleys were grass-covered and that the water after rains flowed over the gently sloping valley floors in the form of sheets. The reason for the present concentration of water and the consequent inauguration of valley-cutting is therefore an interesting question. The Navajos, the native race of the region, connect the change with the bringing-in of sheep by white men and the consequent close cropping of the native grass, coupled also with the fact that sheep travel in droves, often in single file. Thus for two reasons the sheep would aid in loosening the surface detritus and giving the water an opportunity to become concentrated in streams. That this suggestion is a strong working hypothesis is shown by the facts to be observed in the Chin Lee Valley in Arizona. While the main valley and its larger tributaries are barren and cut into by arroyos, one branch is grass-covered and flat-floored and supports willow trees. Water flows in sheets over the surface and is not concentrated in streams. This valley has never been occupied as a grazing area for sheep by the Navajos because of a superstition that it contains certain plants that are injurious to sheep. The suggestion that the inauguration of arroyo-cutting is due to the removal of the grass cover is strengthened by the fact

that dead willows are to be found in other branches of the same valley where grazing has been conducted and which are now deeply dissected by arroyos. For the description of the Chin Lee Valley the author is indebted to Mr. Richard Wetherill, of Putnam, New Mexico.

---

5. *Water Routes from Lake Superior to the Westward.* *By* Lawrence J. Burpee.

Three well-defined canoe routes were discovered at different times, leading from Lake Superior over the height of land to Rainy Lake and the Lake of the Woods. The first of these, in point of time, was the Kaministikwia route; the second was by Grand Portage; and the third by way of Lake Nipigon. The discovery of the Kaministikwia route dates back to the days of the French *régime*. It was discovered before La Vérendrye's day, and became well known throughout the long period of his Western explorations. For some reason this route was completely lost sight of during the period of confusion between the departure of French explorers and fur-traders from the West and the entry of British traders from Canada. It was not, in fact, until the discovery that Grand Portage was within the territory of the United States that the officers of the North-West Company, in searching for a new road, rediscovered the Kaministikwia route. Before this, however, the route by way of Grand Portage had been discovered, and was the recognised highway from Lake Superior to the West throughout the early period of the fur trade under British rule. In 1784 Edward Umfreville was sent by the North-West Company to discover a route by way of Lake Nipigon. A possible route was found, but the rediscovery of the much more convenient route by the Kaministikwia river made it unnecessary to resort to that by way of Lake Nipigon.

MONDAY, AUGUST 30.

Joint Discussion with Section L on Geographical Teaching.

(i) *Secondary School Geography in the United States.* *By* Professor Richard E. Dodge.

Secondary school geography in the United States has largely been physical geography, with or without laboratory work. In recent years the emphasis has been particularly on the physiography of the lands, and the course has been planned to meet the requirements in the subject set for college entrance. In some high schools commercial geography has been introduced as a separate subject, taught mainly from a text-book or as a climax to a brief course in physiography.

While in the earlier years after the introduction of the physiography of the lands in 1893-4 the emphasis was mainly on the scientific classification of land forms according to genesis, in the last few years the work has been expanded so as to include certain of the life responses pertaining to each sub-division (ontography).

Such courses, while strong scientifically, and of increasing worth because of a constant increment in the number of prepared teachers, has not proved of as great value as the times demanded. Students in the high school have not secured a proper basis for the study of history, economics, and other subjects dealing with the distribution of phenomena, and have not received adequate preparation for later study of allied subjects in everyday life or in college. Hence the demand has arisen in the last two years for more usable high school work in geography, for work no less

valuable scientifically than physical geography, but of greater personal use to the pupils.

Hitherto it has only been the rare high school that has included any work in the geographical study of any of the countries of the world. Pupils have in most cities dropped the study of regional geography at the age of thirteen or fourteen years. Nothing akin to the regional work in Britain and Germany has been attempted.

Now educators and geographers have seen the necessity of such work in geography, and the demand for a reorganisation of work along these lines has come from many sources. The National Education Association and the Association of American Geographers have committees at work on the subject, and the new movement is well started. The lines along which geography in secondary schools will develop cannot be definitely prophesied, but it is evident that a change is imminent, and regional geography will probably soon be included in many secondary schools. This regional work will probably be based on the study of certain selected phases of physical geography, and will culminate in a treatment of certain selected regions from a commercial point of view.

(ii) *The Teaching of Geography in Secondary Schools.*
By Dr. C. H. Leete.

The following Paper was then read:—

Some Characteristics of the Canadian Rockies.
By Arthur O. Wheeler, *F.R.G.S.*

The earliest map of the Canadian Rockies, drawn by David Thompson, geographer and astronomer to the North-West Fur Trading Company, in 1813 and 1814, was shown on the screen, and the remarks concerning the travel of early days, with which it is interspersed, were pointed out. Box canyons in the Selkirk and main ranges, cut through bed-rock by glacial torrents, were then shown. Next followed pictures of the Selkirk forests and V-shaped valleys, with snow-clad peaks rising above and ice-falls glistening amid the trees. A description was given of the three series of the marble Selkirk caves, situated near Glacier, B.C., illustrated by flashlight views taken in their interiors.

The climatic conditions of the Selkirks were touched upon, and the several types of glaciers to be found there and in the main range depicted. Samples were shown of the true Alpine glacier, the Piedmont glacier, the ice-cap glacier, hanging glaciers, and the parasitic glacier of Mount Lefroy. A picture, also, was shown of snow-mushrooms. The Spectre of the Brocken was described as a phenomenon of the Canadian Rockies as well as of the Harz Mountains, and two appearances of it, as seen by the lecturer, outlined. A map, with photographic methods of survey, was shown, illustrating the observations now being made of the Yoho glacier by the Alpine Club of Canada, and the methods described. The magnificently coloured glacier lakes were dwelt upon, and a number of pictures of them shown. Ice caves at the snouts of the glaciers were illustrated on the screen as seen from without and from within. Pictures were shown of the ordinary glacial moraine; also of "block" or bear-den moraines, and the theory that the latter are due to seismic disturbance explained. Next were shown a series of waterfalls. The fossiliferous areas of the main range were referred to. Illustrations of the rock-capped earth pillars of Hoodoo Valley, known locally as "Hoodoos," were given; also of some of the numerous hanging-valleys of the region; and of characteristic types of mountain architecture of the limestones of the

main range. Pictures of the animal life of the region and panoramic views from a number of the highest summits were shown.

TUESDAY, AUGUST 31.

The following Papers were read:—

1. *The Relation of Local Mechanical Transportation to the Structure of Modern Cities.* *By* G. E. HOOKER.

The urbanisation of population is the characteristic of this as distinguished from all other historic periods.

In response to this movement a new science has arisen directed to the higher physical organisation of cities with a view to their efficiency, health, and beauty.

The thesis of this paper is that mechanical transportation is the most fundamental and determining factor in modern city structure, and should, in this city-planning movement, be recognised as such and dealt with accordingly on reasonably idealistic lines.

Expanded in statement this thesis is:—

I.—That mechanical transportation is fundamental to the existence of the modern city, has absorbed long-distance and in considerable part local urban carriage, and is destined to extend completely over the latter.

II.—That in the maladjustment thus presented between a traditional city framework and a revolutionary method of transport, the latter has been exercising a profound and largely unguided influence upon city structure, resulting in disordered cities and deficient transport.

III.—That the time has come when the organisation of cities in recognition of mechanical transportation as their central and basic factor should be definitely undertaken, and the following should be the main guiding principles, viz.:—

(*a*) That all the freight and passenger carrying lines and appurtenances of a given city should be combined into one orderly and properly distributed network, in connection with which there should be developed a system for the collection and delivery throughout the city of all freight by mechanical power.

(*b*) That passenger facilities should be developed harmoniously on the basis of continuous cross-city routes.

(*c*) That the primary elements of a great city's framework should accordingly be certain cross-town axial railway avenues and their branches, designed to serve as the trunk factors in a unified and exclusive system of mechanical circulation for both passengers and goods, on which system the balance of the city framework should be articulated.

(*d*) That these factors of transport should, save in exceptional cases, be elaborated in the open air, with differentiated speeds, properly constructed ways, and quieted apparatus, implying healthy occupation for employés, convenience and comfort for passengers, and the minimum injury, where injury is unavoidable, to territory traversed.

IV.—That the modern ideal of a cleanly, convenient, efficient, and widely dispersed city can thus be realised.

---

2. *Yellowhead Pass and Mount Robson, the Highest Point in the Canadian Rockies.* *By* DR. A. P. COLEMAN.

The Yellowhead Pass is well known for its easy gradients through the Rocky Mountains, its highest point reaching only 3,700 feet above sea-level,

so that splendid mountain scenery is scarcely to be expected. It is a surprise, therefore, on reaching the Grand Forks of Fraser River to see Mount Robson rising 10,000 feet almost sheer from the narrow valley. The south-west side, seen from the railway, seems so walled with precipices as to be unscaleable; but on the north-east side, which is covered for 7,000 feet with snowfields and hanging glaciers, three attempts were made to climb it. All were foiled by bad weather, though in one a height of 11,500 feet was reached, about 1,500 feet from the top.

A considerable area of unknown territory was mapped by our party, the first white men to visit Mount Robson.

One of the glacial streams divides its waters between the Pacific and Arctic Oceans, one branch flowing to the Fraser and the other to the Peace River.

---

3. *The Australian Sugar Industry and the White Australian Policy.* *By* Professor J. W. Gregory, *F.R.S.*

Australia in 1901 decreed that the Australian sugar industry must use white labour, in spite of emphatic warnings that the policy meant the immediate and complete ruin of the sugar industry. It was maintained that sugar cane could not be grown in tropical Australia without black labour. The past five years' experience, however, has belied these predictions. The new policy has been so vigorously enforced that the acreage under sugar cane in Queensland cultivated by black labour has fallen from 62.1 per cent. in 1904 to 11.8 per cent. in 1907; but the total acreage in Queensland has increased from 95,697 acres in 1902 to 128,138 acres in 1907. Australia, instead of growing less than half the sugar it needs, as in the black-labour time, now raises practically all; the imports of sugar have fallen from 83,822 tons in 1902-3 to 3,680 tons in 1908-9, while the amount grown in Australia has increased in the same time from 92,500 tons to 195,900 tons. The rateable value of the sugar areas has increased. The white labour proves cheaper than the black in spite of the great difference in nominal wages.

The white settlers, moreover, have a much lower death-rate than the Kanakas. The evidence of the Education Department shows that the children in the tropical towns are as efficient as those in the southern temperate districts of Queensland.

This experiment in the effort to use white labour in tropical agriculture, the greatest yet attempted, has so far proved a success as complete as it was unexpected.

---

4. *The Development of Nantasket Beach.* *By* Professor Douglas Wilson Johnson.

This Paper presented the results of a study of the form of Nantasket Beach, near Boston, Massachusetts, and included a discussion of the stages of development through which the beach has passed to reach its present form, and of the processes by which that development has been accomplished. Nantasket Beach consists of sand, gravel, and cobbles, deposited by wave action between several drumlins which formerly existed as islands. The form of the beach ridges, and their relation to abandoned marine cliffs on the drumlins, prove the former existence of several 'drumlin islands,' now entirely destroyed by wave action. The evidence furnished by the beach on changes in the relative elevations of sea and land was considered, and it is concluded that no such changes have occurred while the beach was forming, a period of one or two thousand years at least.

---

5. *Wauwinet-Coscata Tombolo, Nantucket, Massachusetts.* *By* F. P. Gulliver.

The tombolo connecting Coscata Island with the Wauwinet or eastern end of the Island of Nantucket, Massachusetts, was a continuous bar of gravel and sand from the time of the first settlement of the Massachusetts coast up to 1896. During the fall of 1896 there were several unusually heavy storms, and on December 17, 1896, the sea cut a narrow channel across the tombolo at a point which had been used by the fishermen for many years as a place for hauling small boats from the head of the harbour to the open ocean.

The strong north and north-east storms of the fall of 1908 finally closed this opening, which had moved progressively north from Wauwinet towards Coscata during the years from 1896 to 1908.

Thus on November 12, 1908, the new tombolo was completed, connecting Coscata Island with the Wauwinet headland.

During these eleven years and eleven months, when there was a tidal inlet across the sandy tombolo, the eastern coastline of Nantucket Island had been cut back from 300 to 500 feet.

WEDNESDAY, SEPTEMBER 1.

The following Papers were read:—

1. *The Progress of Geographical Knowledge of Canada*, 1497-1909. *By* James White.

2. *The Economic Development of Canada*, 1867-1909. *By* James White.

3. *A Great Geographer.* *By* J. B. Tyrrell, *M.A.*

The author claimed that David Thompson, of whose achievements but little note has been taken, was the greatest land geographer that the British race has produced.

A poor boy from a London charity school, he spent his life between 1784 and 1812 on the northern part of this continent when it was a wilderness, peopled only by the natives and by a few fur-traders, who had little groups of houses or factories, often hundreds of miles apart, scattered along the principal waterways.

He was a fur-trader in the employ of the Hudson's Bay and North-West Companies, and in the prosecution of this trade he travelled more than 50,000 miles in canoes, on horseback, and on foot through what was then a vast unmapped country, extending from Montreal on the east to the Pacific Ocean on the west, and from Athabasca Lake on the north to the headwaters of the Mississippi River on the south. Wherever he went he made surveys, and wherever he stopped he took astronomical observations for latitude, longitude, and variation of the compass. When he left the Western country in 1812 he had the material for a great map, which he drew in the following year, and which has been the basis for every map of Northern and Western Canada published since that time.

After retiring from the fur trade, he was engaged for thirteen years on the part of Great Britain in surveying the boundary line between the United States and Canada under the Treaty of Ghent, subsequent to which he settled down quietly in Montreal. He died in 1857 at the age of eighty-seven years.

4. *The Progress of the Magnetic Survey of the Carnegie Institution of Washington.* *By* L. A. Bauer.

Since April 1, 1904, when the Department of Research in Terrestrial Magnetism was established by the Trustees of the Carnegie Institution of Washington, a general magnetic survey of the globe, in which various civilised countries are taking part, has been in steady progress, in addition to the work of the said Department which confines its operations chiefly to the oceans and unexplored countries. It is expected that the general survey will be completed at about the close of the next decade.

This paper gave an account of the work accomplished by the Carnegie Institution of Washington during the past five years—one-third of the estimated period of the survey. The three magnetic elements (declination, dip, and intensity) have been determined at some 900 land stations, distributed over the following countries: Greenland, British North America, Mexico, Central America, Venezuela, the Guianas, Columbia, Ecuador, West Indies, Windward and Leeward Islands, various archipelagos in the Pacific Ocean, China, Persia, Asia Minor, Asiatic Russia, Africa, and Europe.

Furthermore, during 1905-8 there was executed a general magnetic survey of the Pacific Ocean in a chartered vessel called the *Galilee*, the aggregate length of the cruises being about 60,000 nautical miles, along which the three magnetic elements were again determined. In some places in the Pacific Ocean it was found that the existing magnetic charts gave declinations as much as 3°, and occasionally somewhat more, in error.

There has just been completed the non-magnetic vessel *Carnegie*, specially adapted for ocean magnetic surveys. She began her first cruise on Saturday, August 21, bound for St. John's, Newfoundland, and Hudson Straits. Upon return to St. John's the *Carnegie* will set sail, about October 15, for Falmouth, England, and then proceed back to Brooklyn, New York, *via* Madeira and Bermuda.

With the friendly and effective co-operation of the countries in which organisations exist for magnetic work we thus have ample assurance that a general magnetic survey of the earth will be completed within the stated time.

---

5. *The Eastern (Tunisian) Atlas Mountains: their Main Structural and Morphological Features.* *By* M. M. Allorge.

This paper was the result of an excursion across the Tunisian Mountains undertaken last Easter in company with Professor Vélain and M. Pervinquière. This area may be divided into the following natural regions:—

(*a*) *Fragments of the Ancient Land of Tyrrhenis.*

Along the coast of Algeria and off the coast of Tunis in the islets of Galita we find the remains of very ancient formations, granite, gneisses, and crystalline schists, similar to those which exist to a greater extent in the islands of Sardinia, Corsica, and Elba. These are probable indications that we are here in the presence of the southern boundary of the ancient land of Tyrrhenis, now sunk beneath the waters of the Mediterranean.

(*b*) *The Sandstone Mountains of Khroumirie.*

This range, together with the mountains of the Apennines and of Sicily, forms a part of the Tertiary system of mountains surrounding the old Tyrrhenis. The main ranges of Khroumirie trending from the south-west to the north-east are apparently a continuation of the Saharian Atlas,

The trend lines of the Mediterranean Atlas, which are well developed in Algeria, run from west to east, and seem to disappear gradually toward the east before reaching the Tunisian frontier. They do not extend into Tunis except in the shape of fault lines and lines of displacement, which interfere with the other trend lines, producing a confused topography. These regions of Tertiary sandstone have still retained their forests of evergreen oaks and cork oaks, while the softer Cretaceous Marls are carved into vales covered with rank grass. The course of the Medjerda River divides these regions from the division treated of in the next paragraph. This river, flowing through a series of fertile alluvial depressions, has in a remarkable manner forced its way through the surrounding mountains, and, instead of following a continuous longitudinal valley, it drains series of fertile elliptical plains, joined by steep gorges cutting through the intervening anticlines. Most of these gorges have probably been originated by the capture of the higher lying depressions by the lower ones; in some cases it is even probable that the capture was at first subterranean, and that some of these canyons have been formed by underground erosion and by the subsequent subsidence of the roofs of the caves.[1]

(c) *The Central Upland of Tunis.*

In the central district we find a rolling upland, consisting of a series of dome-like elevations, running in more or less regular lines and broken by elliptical depressions. These structures have probably been brought about by the superposition of the Atlas folding running south-west and north-east upon an older system running in meridian directions, and which is more visible in the far south. The formation of these domes and basins might be illustrated by compressing a sheet of corrugated iron in such a manner as to produce a new series of corrugations crossing the original ones obliquely.

(d) *Continuous Ridges of the South.*

Toward the south we find elongated upfolds running parallel east and west, and dividing Tunis proper from the Sahara. Rich phosphatic deposits have been found in the Eocene limestones forming the flanks of these anticlines.

(e) *The Margin of the Desert.*

Along the foot of the southern ridges we find a series of alkali flats and salt lakes, locally known as 'Shotts,' containing a large amount of chlorides of sodium, magnesium, and iodine. At a few points, where fresh water is available, are located the flourishing oases of the Djerid. These oases have been compared to natural greenhouses irrigated with hot water, the temperature of some of the springs reaching over 90° Fahr., giving to this group of oases a decided advantage in bringing to early maturity the dates, fruits, and vegetables, which are the chief source of wealth of this region.

(f) *Coastal Plains (locally called 'Tunisian Sahel').*

These extend east of the central uplands to the coast. They are fertile lowlands of recent origin, covered with plantations of olive-trees and limited toward the east by sand dunes.

---

[1] There is a striking contrast between the meandering habits and the mature character of the river in the longitudinal depressions, half filled up with its own alluvions, and its youthful and energetic behaviour in the transversal canyons.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

President of the Section.—Professor S. J. Chapman, M.A., M.Com.

THURSDAY, AUGUST 26.

The President delivered the following Address:—

After searching for some time for a topic for this address suitable to Winnipeg I finally made a choice which may not commend itself at first as a happy one. It is not a topic of immediate local interest, but at a distance of nearly 4,000 miles I was not in a position to discover the economic problems the treatment of which would immediately arrest the attention of the people of middle Canada at the present time, and had a wizard's wand disclosed to me such problems I should not have been able to solve them on paper from the other side of the Atlantic. And yet my subject has a direct reference to Canadian affairs, though the extent of this reference is not apparent till we look ahead and view things in perspective. It occurred to me after a cursory examination of some recent examples of that remarkable modern crop of Utopias and anticipations which apparently are appealing to an extensive public. If only these 'new worlds' represented what existed somewhere among human beings with passions and infirmities like our own, 'How much more instructive they would be!' one was naturally led to reflect. You will see now the train of suggestion fired in my mind. Clearly, if the gaze of humanity is repeatedly drawn to its future, a visitor from a land of advanced industrialism who had made that industrialism his study, in speaking, in a country as yet thinly populated and young in industrial experience, of some of the most urgent problems which industrialism brings with it, might expect a hearing at least as patient as that which a very minor prophet would win. Now among the most insistent root problems to be found in our great industrial city civilisations are those which group themselves around wages, conditions of work and living, and the hours of labour. From this group I have chosen the problem of the hours of labour as the one which has not, perhaps, received the same measure of practical consideration as the rest. Expressed in another way, our topic is the value of leisure, the bearing of industrial development upon it, and its effectiveness in shaping economic arrangements. The demands continually made for shorter hours and a normal day, the claim, now extensively supported among Western peoples, that the State should intervene, and the fact that some Governments have intervened, even to the length of regulating the hours of adult male labour, are additional grounds for trusting that this topic will be at present of more than academic interest.

We naturally inquire at the outset why the question of leisure does not assume prominence until modern industrialism has supplanted a simpler economy, and why much less is heard of it among agricultural than among industrial communities? In the hand industries of the past the hours of labour were excessively long in comparison with modern industrial standards, and among the peasantry and pioneering farmers work never wholly ceases in waking hours throughout much of the year except for short breaks for meals; and yet little complaint would seem to have reached us from either source. The explanation may lie partially in the fact that new grievances emerge with the spread of the wages system—the problem of the working day does not present itself in quite the same light to wage-earners and to the self-employed—that these grievances are rendered more articulate by group production; and that the aggregation of people of one economic class in dense packs gives unanimity and volume to the demand for reform. The hardships suffered by a scattered population, occasioning discontents, which, however, stop short of provoking outbreak, seldom succeed in attracting public notice; and people acting in isolation are naturally timid. But this, I think, is not the sole explanation. The character of much of the world's work has changed, and so have the demands made upon leisure.

Industrial work on the whole has certainly become more regular and continuous throughout the year, and analysis would seem to show that work per unit of time gets more severe, in a sense, as communities advance, though no doubt a strong case could be made out for the view that the trend of economic progress is towards an end in which the character of labour generally will be far more conducive both to satisfaction and to human development. I am not so optimistic as to suppose that mechanical improvements do not frequently bring with them a new monotony of work, though higher wages may prevent them from forcing greater monotony of life upon those who suffer from the new monotony of work. Mechanical improvement proceeds by 'specialising out' mechanical tasks, the performance of which by hand must be a dreary occupation, but each step in the march of invention seems to create, as a rule, by its incompleteness, tasks meaning a new and more concentrated monotony, though no doubt it must generally result in an appreciable reduction of the amount of dull employment involved in the attainment of a given output. Any work must be wearisome the pace of which is set by a machine and kept absolutely steady. We may usefully compare mechanical improvements with discoveries relating to the utilisation of by-products. The latter always recover from refuse something of value to the community, but they generally leave a refuse more concentrated than that with which they began.

The road of economic advance is by way of specialism, and just as there has been specialism in tools and in division of labour, so there has been a specialism of labour in working hours and of leisure and social intercourse in non-working hours. Specialism on the one side implies the elimination of waste, whether of means or of time, and it has therefore meant to the labourer the partial or occasionally complete elimination of the leisure with which his working hours used to be plentifully interspersed. In a modern workshop, noise, the necessity of discipline, or a continuously absorbed state of the attention, have frequently reduced the possibilities of conversation to the barest limits. Humanity has no doubt been relieved of the heaviest burden of toil by inventions relating to the mechanism of production, but their application has been accompanied on the whole by the closer concentration of some kind of effort in time. The intensification of labour in a more confined sphere of activity may, as Professor Münsterberg argues, exercise more fully the higher human faculties and thereby bring with it a deeper interest, but it will almost certainly prove more exhausting, even apart from the elimination of change, leisure, and social intercourse. And decade by decade, with the 'speeding up' of machinery, we should

expect to find more nervous strain accompanying the process of production. That industrial functioning has become a severer tax on the energy of the workman is fully borne out by the evidence of numerous reports upon industrial conditions.

The increasing nervous strain of industrial work, whether it results from the progressive specialisation of labour or not, would account sufficiently for the curious circumstance that there is apparently no finality about any solution of the ever-recurring problem of the normal working day, though it is not the sole explanation. The workman whose day has been reduced is soon repeating again his demand for shorter hours, and there are pessimists who infer from this that the shorter hours attained hitherto have shifted the community on to a slippery inclined plane which leads from the economic 'struggle for existence'—by which is meant the competitive striving for place, reputation, and achievement, whereby progress is naturally stimulated—to economic stagnation. They think they discern in the present generation a growing disinclination to make an effort and a growing disposition to take the easy path; but that the truth cannot be mainly with the pessimists an examination of the effects of curtailments of the daily hours of labour upon output would at least suggest. A mass of material exists in official and other reports in more than one advanced industrial country for a study of this question. Beginning with the writings of Robert Owen and Daniel le Grand, both of whom laid especial stress on moral and social elements, an investigator would find an almost unbroken sequence of evidence. Mr. John Rae collected a volume of facts in 1894, and these may now be supplemented by the experiences of yet another half-generation.[1] Limitations of space forbid that I should quote examples, but I may at least roughly generalise from the recorded facts. I have found no instance in which an abbreviation of hours has resulted in a proportionate curtailment of output. There is every reason to suppose that the production in the shorter hours has seldom fallen short by any very appreciable amount of the production in the longer hours. In some cases the product, or the value of the product, has actually been augmented after a short interval. In a few cases the reaction of the shorter hours on the output per week has been instantaneously noticeable, and the new product has surpassed the old product before mechanical methods could be improved. Further, for some industries—for instance, for the Lancashire cotton industry—we have preserved for us the results of a string of observations reaching back about three-quarters of a century, and it would appear from them that the beneficial effects wrought upon output by the shortening of hours were substantially repeated, though, of course, in different degrees, at each successive reduction of the working day.

So far I have directed your attention mainly to two incidents bearing upon the hours of labour: the one, the effect of industrial development in curtailing the hours which result in the largest daily output; the other, the subjective effect of the increasing strain associated with such advance. I have now to add another influence, which is the enhancement of the value of leisure which must accompany a rise in wages, improved education, and social progress generally. It must be insisted that the amount of the real wage yielded by a given money wage varies as the time left to spend it; and, further, that the value of leisure is a function of the goods which can be enjoyed in the period of leisure. The acute operative would aim at so distributing his time between work and recreation that the gain resulting from a little more leisure would equal the loss consequent upon the implied diminution of wages. Hence, when the volume of goods per head annually supplied to labour was augmented, an attempt would almost certainly be made by the operatives to buy more leisure, even if the satisfaction derived

[1] Note in particular the Report of the Industrial Commission of the United States.

from leisure were unaffected, which it would not be, because the satisfaction derived from leisure must rise when each hour of leisure is enriched by greater possessions. As regards the effect of education, it is sufficient to point out that the value of leisure is a function of appreciative power and that this is developed by education, but it must be observed that the higher appreciative power might enhance the satisfaction got out of the work itself, and that this effect might conceivably counteract the effect on the value of leisure, or even more than counteract it. Ambitions would be further awakened ; but the ambitious operative would probably demand, as a rule, more time for study. I think it unquestionable that, on the whole, educational advance causes a curtailment of hours. 'But unfortunately human nature improves slowly, and in nothing more slowly than in the hard task of learning to use leisure well. In every age, in every nation, and in every rank of society, those who have known how to work well have been far more numerous than those who have known how to use leisure well. But on the other hand it is only through freedom to use leisure as they will that people can learn to use leisure well: and no class of manual workers who are devoid of leisure can have much self-respect and become full citizens. Some time free from the fatigue of work that tires without educating is a necessary condition of a high standard of life.'[1] Social progress, broadly regarded, by complicating life and rendering vague feelings of social obligation definite and more insistent, creates new claims on leisure. 'Generally it can be said that the more complex the social organism becomes, the more its constituent individuals must devote time, apart from work and business, to the family and recreation, to education and general affairs, the more necessary is a general social arrangement concerning the distribution of time between the several purposes which it has to serve.'[2]

The eight hours day has come to be regarded by some social reformers as the ideal of the future. The doctrine that the workman should normally work eight hours a day has been put forward as holding at least as generally and with as high a degree of certainty as, say, the doctrine that the workman should normally sleep some definite number of hours a day. But I should argue that the problem of the length of the working day is of an order different from that of the problem of the time which should be devoted to sleep, for whereas the hours which should be given to sleep depend mainly upon physiological conditions, though these physiological conditions are affected by economic and psychological conditions, the hours which it is wise to assign to labour depend upon the attitude of the workman to leisure and work, which results as much from non-physiological as from physiological influences. It is my purpose to demonstrate that the non-physiological value of leisure, as well as its physiological value, must rise with progress, and, therefore, that in all probability the hours which should normally be worked per day will become steadily less. The ideal working day of the future cannot be eight hours, for it must be essentially a progressive ideal. As a community advances agitation for shorter hours will be constantly breaking out anew. If this be a correct reading of progress, it is important that we should understand fully the forces at work at each re-settlement of the length of the working day, those on the employing side as well as those expressed in the claims of the operatives. I propose now, in consequence, to disentangle the impulses and their relations, into which the question of the determination of the working day at any one time may be resolved.

The problem being elaborate, it is essential that we should proceed by successive steps of abstraction. We need not be afraid in this age of under-

[1] Marshall, *Principles of Economics*, 5th ed., pp. 719–20.
[2] Schmoller, *Grundriss der allgemeinen Volkswirthschaftslehre*, p. 741.

standing of having recourse to abstraction; it is a method without which every scientific study, whether philosophy, biology, physics, or what not, even history, would be impossible. In the first instance, therefore, I intend to indicate the length of working day which operatives and employers would respectively seek if they recognised their own interests and were endowed with complete foreknowledge of the effects of different hours of labour upon their interests. I shall assume—as I may legitimately for ordinary factory employment—that the workman tends to get as his wage his marginal worth, that is to say, the value which would be lost by his dismissal. We may assume, further, that the marginal worth of the workman for any given working day becomes in the long run a stationary amount. If the efficiency of labour rose continuously in consequence of a reduction of hours it would obviously approximate to some limit, and if it fell continuously in consequence of an extension of the hours of labour it would equally approximate to a limit. After some time the differences between these limits and the actual efficiency of labour could be taken as negligible. Merely for the sake of simplicity, I shall now suppose that one kind of labour only is employed. It is clear, then, that it is possible on these assumptions to indicate what in the long run (*i.e.*, when all the reactions, as regards, for instance, the efficiency of labour and provision and arrangement of other agents, have taken place) the marginal daily worth of labour will be for different lengths of working day, it being understood that the number of shifts worked remains the same. If the number of shifts were increased the value of the labour would rise, as will be fully explained later. Let us suppose that the following table represents, at a given time, the value of labour of a given kind per week in relation to the length of the working day:—

Hours per Day.	Value of Labour per Week in Shillings.
6 . . .	34
7 . . .	38
8 . . .	40
9 . . .	41
10 . . .	40
11 . . .	39
12 . . .	37

The fall in the value of labour after the working day exceeds nine hours is due to the fact that diminished weekly productivity more than counteracts the direct effect of the extension of the daily time for work. The diminished weekly productivity may be due to impaired vitality—physical, mental, or moral—or to some extent to irregularity, where that is possible, as in the case of colliers. The damage to productivity may be inflicted directly by excessive work, or it may be indirectly consequent upon it, the prime cause being found in the use of stimulants or recourse to unhealthy excitement in periods of leisure, reactions which are only to be expected when the day's work is very exhausting or very dull. The use of leisure affects, of course, mental vitality, culture, and character, and it will therefore be generally observable that labour which has had its hours reduced will be capable after a time—when the use of leisure has been improved and the improvement has produced its effects—of managing satisfactorily more complicated machinery, and will be generally more responsible and trustworthy, and therefore less in need of continuous watching and directing. Now, clearly, if employers are endowed with the foresight presupposed, and if their hours of work need not increase concurrently with a lengthening of the working day, it is in the case supposed to their interest collectively to come to an agreement not to employ labour more than nine hours a day, and to their interest individually not to employ labour for shorter hours than nine a day. The second conclusion follows from the fact that the weekly product would be

augmented by a greater amount than 1*s.* multiplied by the number of operatives were the hours of labour increased, say from eight to nine, because labour, as every other agent employed in production, is paid not its aggregate but its marginal worth to the business in which it is employed. This proposition may be made more self-evident by the following example. Were labour rendered 25 per cent. more productive all round, the product and real wages would each be raised approximately 25 per cent., other things being equal; but as the product must be greater than aggregate wages the addition made to the former by the longer hours must be greater than the addition made to aggregate wages.

Next, suppose that an agreement between employers, tacit or overt, is impossible, and that each employer will make what he can when he can. What hours, then, will competition among employers tend to bring about when humanitarian considerations and any resistance from the operatives are ruled out? Suppose the efficiency of labour at the time is that associated with a customary working day of ten hours. The product of the last fraction of the tenth hour could not be zero, for, if it were, ten hours would not be worked. The ultimate effect of extending the working day beyond nine hours is loss, not because the product of the last fraction of the ninth hour is zero, but because the product of the last fraction of the ninth hour just equals the ultimate reduction of the product of the other hours occasioned by the lengthening of the working day. Hence, on the assumption that employers are perfectly far-sighted, but that agreement between them as to working hours is lacking, the disposition on the part of each employer to reduce hours to nine would be weakened if each employer could not depend upon keeping operatives after he had brought them to the level of efficiency associated with the nine hours day. The reforming employer would run the risk of paying the whole cost of the labour value created by shorter hours and getting little in return; other employers might secure and exhaust the new labour value, and no permanent good would be effected. Nor would there be any more guarantee in the conditions supposed that the nine hours day would be retained, if instituted, for an employer could always snatch a temporary advantage by extending hours and paying slightly higher weekly wages. This is a general proof that, on the assumption made as regards the intelligence and foresight of employers and in the absence of agreement between them, the hours resulting in the maximum product would not necessarily establish themselves, no force on the side of the workpeople being supposed operative.

I now pass on to analyse the determinants of the operative's choice in the matter of the hours of labour, assuming that his wage equals his marginal worth and that he knows it, and supposing in the first place that he is endowed with perfect prevision. Two things affect him which do not appeal to the self-interest of the employer, namely, the direct value of his (the operative's) leisure and the balance of satisfaction or dissatisfaction which his work yields of itself. Here I must interpolate the remark that by 'satisfaction' or 'utility' in this address I merely intend a conventional objective representation of the subjective fact of preference, behind which the economist *quâ* economist cannot penetrate. I say this in order to evade the charge so frequently made against economics that it implies the acceptance of Utilitarianism, psychological or ethical. Picking up again the main thread of our discourse, we observe that, apart from the two considerations mentioned above, namely, the value of leisure and the satisfaction got directly from the activity of labour, the operative's real income is maximised when his money income is maximised. Hence apart from these two considerations the choice, as regards the length of the working day, of perfectly far-seeing operatives would be the choice of far-seeing employers were the latter combined. Now take the value of leisure into account. Any daily duration of production being premissed, if the utility

derived from an incremental addition to leisure is greater than the utility of the increment of wage sacrificed by transferring an increment of time from production to consumption, the operative would gain from a contraction of the working day, other things being equal. Recurring to our earlier numerical example, we see that from the long-sighted point of view the productivity of the last fraction of the nine hours day is zero while its value as leisure must be greater than zero. Hence the operative would choose to work less than nine hours a day, it being understood, remember, that he is paid his marginal worth and knows what that will be for different daily periods of work. Leisure consists in rival satisfaction-yielding occupations, active or passive, which are rendered possible by wages. There is consequently a close connection between this and that other determinant of the operative's choice, namely, the positive or negative utility associated with labour itself. It may be granted that in the long run, after the working day has exceeded a certain length, any further addition to it diminishes the satisfaction directly derived from working or adds to the balance of dissatisfaction. If a balance of dissatisfaction were associated in the long run with the efforts of the last minute in the working day which the operative would otherwise choose, as would ordinarily be the case, he would elect, other things being equal, to work an even shorter day, the duration of which would be determined at the point at which the gains and losses came to equivalence when everything was taken into account—that is to say at the point at which his satisfaction was maximised. Did the last minute of working still yield satisfaction in the long run when the hours were nine (referring to the case supposed), which is so highly improbable as to be a negligible case, the operative would prefer to devote more than nine hours of his day to production were this satisfaction of working greater than the value associated in the long run with the last minute of leisure left when nine hours a day were given to business.

So far in considering the operatives' interests we have fixed our eyes on a remote perspective. We next focus our attention upon immediate tendencies and suppose them not to be counteracted by forces arising out of a regard for ultimate results. In these circumstances the operative would be inclined to select a longer working day than that which would be continuously the most advantageous to him, because he would be blind to the reaction of the longer hours on efficiency and so on earnings and the capacity to take pleasure in work. Many people lower the general level of their earnings in the future, and spoil their enjoyment of work and leisure in the future, by making as much as they can in the present. However, even in these circumstances operatives would not approve such long hours as employers who were short-sighted, because the latter would make no allowance for the disutility of labour to the operative or the utility to him of leisure.

We are assuming throughout, it must be remembered, that the wage will always be the operative's marginal worth—that is, what would be lost if he were dismissed—and that he knows it. Actually, of course, there is frequently an appreciable discrepancy between the marginal worth of labour and its wage, and the usual connection between them has not been commonly understood by the wage-earning classes. It would seem from the records of labour movements as if the operative's fear—based as much on ignorance as on distrust—lest the longer day should mean no more pay, though the weekly product would be greater, has protected him against the injurious consequences of short-sightedness; but I am inclined to think that the dominant force in these labour movements has consisted in ideals of life, formed half instinctively, which are unconnected with views, fallacious or otherwise, concerning the mechanics of distribution. Bad arguments have been used to justify good ends. To these ideals of life I shall refer again.

In reality the actions of both employers and employed, in so far as they are governed by self-regarding impulses, will be compromise resultants of immediate impulses and long-sighted calculations. Long-period results which are not very remote will usually be appreciated, and employers as well as operatives may aim at them, because the former may think the length of time an operative usually stays with one firm sufficient to justify a slight present sacrifice made with the object of securing improvement in the operative's efficiency.

The above analysis explains not only disagreements between employers and operatives as regards the normal working day, but also the friction which is constantly generated in the matter of 'overtime.' Without the admission of overtime heavy losses might be experienced by an industry in view of the inelasticity of its production and fluctuations in the market in which it sold; but, on the other hand, overtime once admitted sometimes tends to be worked out of proportion to the special need for it, and operatives are apt to suspect that it is being used unfairly to extend the normal day.

I now desire to compare specifically the effect on wages with the effect on the working day of the mechanical action of pure competition. In the matter of wages, if operatives were too weak to have much influence in settling their pay, competition between employers, were it keen and unchecked by combination, would at least secure to the operatives as a wage, for a given working day, their marginal worth (within limits set by social friction) in view of their then state of efficiency. Thus in the circumstances supposed the operative would tend to get approximately the utmost possible —apart from the question of the reaction of wages on efficiency—in an active society reposing economically on a basis of freedom of enterprise, for we may take it that in such a society the bidding of individuals against one another for labour would continue at least up to the known marginal worth of labour. Observe, however, that the existence of such bidding may imply that new businesses are being established, or that old established employers are anxious to make considerable extensions, for old established employers, knowing that similar workmen must be paid the same, might avoid courses of action which resulted in a gain less than the loss involved in the elevation of wages. It is doubtful whether employers would as a rule assume that if they did not take steps leading to an advance in wages others would do so, for, not unnaturally, employers are commonly indisposed to disturb rates of wages except for strong reasons. And in the cases in which competition is effective in raising wages to the marginal worth of labour, it must be remembered that employers, even if endowed with a powerful telescopic faculty, would not necessarily be induced by self-interest to offer the wage in excess of the operative's worth at the time which would ultimately produce (by augmenting the bodily and mental vigour of the operative) efficiency value equal to it, for their precautionary instinct would attach weight to the apprehension lest some of their operatives should leave them and carry to rival employers the proceeds of the long-sighted investments thus made in them. Other things being equal, of course, the higher the efficiency of labour the greater is the gain not only of the workmen but also of the employer. Now, as regards the working day, we have already seen that uncombined employers might keep it longer than would be desirable from their point of view, for the same reasons for which they might keep wages lower than would be desirable from their point of view. These reasons are, I repeat again, short-sightedness, or fear of incurring an expense the fruits of which other employers might reap. In this respect competition between employers is equally defective in its bearing on wages and in its bearing on the length of the working day. But it has an additional defect, as regards the amenities of working class life, in its bearings on the length of

the working day; for though competition between employers in an enterprising society would bring about the degree of devotion of time to production which the operatives would choose at the wages rendering it possible, the choice of the operatives is apt to be governed by a circumscribed vision which is partially blind to the responses of efficiency to abbreviated hours.

It would seem, therefore, that two reasons at least can be derived from economic theory for State intervention in the matter of the hours of labour, if it be assumed that the State can discover what is best for the country. The one is to correct the tendency of people engaged in industry to agree upon an amount of sacrifice to money-making, which means a large future loss, involving the next generation, for a small present gain; the other is to fortify, if needful, the resistance of operatives to the disposition of some employers to secure a greater product at the expense of the operatives' convenience. This conclusion would, however, be too hasty a deduction. Economic matters are settled, not merely by the self-regarding forces which we have hitherto emphasised, but also by social conceptions, embodied in public opinion and class notions of what is right and proper, which defy expert analysis and any accurate evaluation as influences. These social conceptions, which are not deliberately framed on a rationalistic basis, but proceed insensibly as it were from the needs of human life, are less intermixed with religious elements now than they used to be, but are none the less powerful. Resting on the seventh day is not at present a religious observance to the extent to which it has been in certain periods of past history, but it has not universally been found necessary to supplement the declining religious sanction with the legal sanction. How far progress which runs counter to tendencies determined solely by self-regarding forces may be left with confidence to the operation of these incalculable motives which sway every community, can be settled only by careful observation. It is sufficient now to recognise their existence, and to point to the reductions of the hours of labour in recent years. I do not propose to consider here, in the light of the existence of these incalculable motives, the merits and demerits of the method of legal enactment for attaining the ideal in the matter of the daily duration of toil, except to observe, first, that Government interference which aimed at securing reasonable hours for adult males in all the diversified industries of a country would entail elaborate, elastic, and frequent legislation, and would no doubt be accompanied by many grave errors; and secondly, that a *prima facie* case can be made out for the regulation of the hours even of adult males by authoritative boards, Order of the Home Office, or by statute, when labour is weakly combined and hours are evidently sweated hours, and evidence is forthcoming that they are detrimental to health or vigour. Nor do I propose to consider whether it might not be better to suffer for a time present ills in the hope that there would grow up in the community an adequate power of self-regulation, which would incidentally be accompanied by highly valuable social consequences, outside the sphere of our present inquiry, that otherwise might never have been elicited. I am hopeful that the intangible force of public opinion, directed by economic and ethical enlightenment over a field rendered yearly more co-extensive with contemporary facts in consequence of the growing demand for publicity and the response made to that demand by governmental authorities and the press, will become in the future an increasingly efficacious factor in progress, apart from its expression in law. Even to-day, in view of the dependence of producers on demand, neither employers nor trade unions can afford to brave for long public sentiment, though unorganised, when it is deeply stirred; and public sentiment in the years before us may be expected to respond more sensitively to incidents in its surroundings which offend against social conceptions of what is right and proper. The cases of children, young persons, and women, which

bring in special considerations, must be ruled off from the subject matter of this address.

There is no doubt but that all advanced industrialism to-day is feeling the strain of an accumulation of forces tending to bring about an abbreviation of the working day, and that it will be subjected to the same strain in the future. Now, in relation to this experience, it is disturbing to notice that a close-set limit is imposed upon reduction of hours by the heavy interest and depreciation charges with which the product of a machine is burdened when it works only a fraction of the time for which interest must be paid. As regards depreciation it must be observed that buildings deteriorate in value at least as much when shut up as when they are occupied; that machinery continues to wear out, and sometimes rapidly, when it is idle; and that the reserve fund necessary because the market may contract at any time, and because machinery may at any time be rendered obsolete, is independent of the length of the working day. Many inventions involve an extended use of capital per head, though all do not, and interest and depreciation charges are on the one hand interdicting the application of some of those new ideas to industry which do necessitate heavier capital investment, and on the other hand preventing those applied from reducing hours so much as they otherwise would.

The weight of the discouragement indicated above to the shortening of the hours of labour depends, of course, upon the relation between wages and payments for capital in the expenses of a business, and this relation varies with the industry. A rough calculation, nevertheless, for a particular industry of the saving in hours which might be effected by the continuous running of plant will not be altogether irrelevant. In the industry for which I have obtained figures, interest and depreciation would be reckoned ordinarily at 10 per cent. on the capital, about half for each, while wages would be in the neighbourhood of $12\frac{1}{2}$ per cent. Now, it is being assumed provisionally that the depreciation charge varies as the hours worked, that the rate of interest is a constant, that the equipment of the industry remains as before and labour tends neither to leave the industry nor to flood into it, and that other costs of production are not affected, we find that hours could be reduced from ten to eight without any loss of wages, were the continuous running of plant substituted for the ten hours day.[1]

[1] The calculation is as follows:—

Interest	= 5	per cent. of capital.
Depreciation . . .	= 5	" "
Wages	= $12\frac{1}{2}$	" "
∴ Wages + Interest . .	= $17\frac{1}{2}$	" "

Continuous running would mean increasing the annual duration of production in the ratio of $\frac{24}{10}$. Hence, with continuous running,

$$\text{Wages} + \text{Interest} = 17\tfrac{1}{2} \times \frac{24}{10} = 42 \text{ per cent. of capital.}$$

And, as the capital remains as before—

Interest	= 5	per cent. of capital.
Wages	= 37	" "

Writing x for the daily hours worked per head which would yield the same weekly wages as before, we have

$$\frac{37}{24} \times x = \frac{12\frac{1}{2}}{10} \times 10.$$

$$\therefore x = \frac{300}{37} = 8 \text{ (approximately).}$$

Actually, of course, some of the gain would be taken in the form of higher wages. Further, it must be noticed that the assumptions made do not accurately correspond with fact, though they are satisfactory for the purposes of a first approximation. On the one hand they lead to an over-estimate of the advantages of continuous running, because twenty-four hours of work could not possibly be squeezed into a twenty-four hours day, and because the cost of artificial light during night work is disregarded, as are also the costs connected with awkward points in organisation, with the sharing of responsibility for the proper treatment of machinery, and with the fact, universally experienced, that night-shifts are not so productive as day-shifts. On the other hand, they lead to an under-estimate of the advantages of continuous running, because the cost of depreciation, as we have seen, is not proportional to the daily hours of work,[2] because the shorter hours would raise the efficiency of labour, and because the demand for capital would be reduced, as would also the demand for land for manufacturing purposes. The inevitable contraction of the demand for capital is a point to be emphasised. If working hours per day were raised from ten to twenty-four, then, the reaction on the efficiency of labour still being disregarded, the old output could be obtained with five-twelfths of the old capital: the consequence would be a fall in interest, an augmentation of the amount of the plant per head of the people working with it at one time, and therefore an increased output per head.

In view of its great economies, the shift system calls for very careful consideration. The magnitude of the advantages which the wage-earners might hope to derive from its more extensive application has been denied, on the ground both of theory and of experience of those businesses in which it has been tried. But theoretic objections of a fundamental nature will be found to reduce to false doctrine concerning the determination of wages; and it must be remembered that as the benefits accruing from the comparatively few cases in which the shift system is practised are by competition spread over the whole community, the gain of any individual is cut down to a very small figure. It must not be supposed that the effect of its universal adoption would be equally inappreciable. Without general recourse to shift systems I cannot see any immediate prospect of much additional leisure for the mass of the population. Shifts could be designed so that no one shift would be particularly disagreeable to work in, and, if all shifts did not offer equal advantages, the operatives could be moved round, being assigned for so many weeks to each shift. The shifts for foremen, and the management generally, which would have to be strengthened, might be arranged to run over a portion of two operatives' shifts, so as to cement the new work on to the old; and the connecting of the work of each shift with that of the shift which it followed could also be secured by arranging that the unit of labour should be a group of partners, consisting of one man from each shift, it being the duty of each man before commencing work to see his partner in the displaced shift and receive instructions from him. Naturally, a shift arrangement could only be introduced gradually. Are the objections to shifts of such gravity as to counteract their immense economies? The fact that an affirmative answer was generally given to this question in the past is no proof that the affirmative is the right answer to-day in England, or even in industrial Canada. Conditions have been revolutionised in the last fifty years. Improvements in artificial lighting and in intra-urban transportation have alone swept away a mass of the conditions underlying the evils which used to be associated with night work. And two or three shifts of approximately seven hours each, or

[2] Had the depreciation been taken as independent of the hours of work the calculation in the previous note would have pointed to a seven hours day instead of an eight hours day.

three or four shifts of approximately six hours each—I state a not immediately attainable ideal—are very different in their effects upon social life, exclusive of those associated with the shorter period of toil for each workman, from two shifts of some ten or eleven hours each. With the shorter shift in use, arrangements could be made without much difficulty for all operatives to get most of their sleep in the night, if they so wished, and to enjoy most of their leisure in daylight. But it is not my intention in this address to make a practical proposal, or argue points of detail. I merely present certain theoretic corollaries which have incidentally been derived from our analysis of conditions determining the length of the working day. In conclusion, I may quote Dr. Marshall's final judgment that were shift systems more extensively adopted 'the arts of production would progress more rapidly; the national dividend would increase; working men would be able to earn higher wages without checking the growth of capital, or tempting it to migrate to countries where wages are lower: and all classes of society would reap benefit from the change.' [1]

Let me now summarise my main conclusions, and humanise them by restoring the moral and social elements from which our premisses were to some extent abstracted. I have hitherto spoken of progress in such terms that the critic would have some excuse for charging me with narrowness of vision. Progress is not summed up in improvements in productive methods which reduce the cost of things, nor in these improvements combined with the application to production of ideas which render work pleasanter and more educative. Nor is it wholly, or in bulk, summed up even if we add improvements in distribution (resulting in a more satisfying sharing of wealth) and a greater responsiveness of production to the needs of the community. The essentials of what most of us really understand by progress are to be found only in the world of consciousness—in the spiritual constituents of the universe. I mean what we cannot exactly define if we are not philosophers—and hardly then—but something implying a full living, with understanding of life and its surroundings, including its ethics, and a living with volitional powers strong enough to enable us to follow our lights. As all this is actually, though vaguely, desired in some degree by humanity generally, it is no doubt covered by the satisfactions measured in demand, but the admission of its reflection on one plane cannot be regarded as its adequate inclusion in our social philosophy. The most important aspect of the question of the length of the working day consists in its relation to the most intimate constituents of progress. Let us call progress in this sense 'culture'—a term perhaps the best of the single terms available to convey my meaning. Now the world appears to be so designed that culture has on the whole a proportionately important place in the most primitive economic conditions. The hours of labour in such conditions may be long, but work is not so continuously absorbing that social intercourse during work is impossible, while variety of experience, contact with nature, and the calls made on initiative, afford that intimacy with life as a whole, and that evocation of moral forces, which must be obtained in later stages of civilisation largely through systematic education and books. I have argued above that each step in civilisation brings intensified specialism. Work is by no means rendered non-cultural ultimately, but its cultural aspects are specialised, as are its objective aspects. Interest may be deepened on the whole, but it is no longer diffused; the need for thought and purpose may be no less than before, but the thought and purpose are of a confined character. The intensification of economic life which is implied is in itself all to the good, but the community must lose something of culture unless, corresponding with this intensification, there is an expansion of leisure and a specialised use of leisure for the purposes of culture.

[1] Marshall, *Principles of Economics*, 5th ed., p. 695.

Certain expressions which have come into common use would seem to be significant of the needs and dangers of an industrial society highly advanced on the technical side. Thus we speak of the 'cultured' classes and the 'leisured' classes. For the attainment of culture, leisure is essential to-day as it was not in the past in quite the same sense, 'culture' being broadly defined. I need not say that a 'progress' which meant the 'specialising out' of leisure for the sole enjoyment of one class would not commend itself to any reasonable person; and I do not discern any danger of 'progress' of this sort; but there is some danger lest the growing importance of leisure generally, and of a proper use of leisure, should not be fully realised. Tangible things force themselves upon our attention as the more intangible do not, and some of us who have an economic bent of mind get into the way, in consequence, of thinking too much of the quantity of external wealth produced and too little of the balance between internal and external wealth. In ultimate terms, to those who care to put it that way, all wealth is life, as Ruskin insisted. There hardly appears to be any risk of a general underrating of external goods, but there is some risk of an underrating of the new needs of the life lived outside the hours devoted to production—which should themselves be, not a sacrifice to real living, but a part of it—and of an underrating of the dependence even of productive advance upon the widespread enjoyment and proper use of adequate leisure and an adequate income.

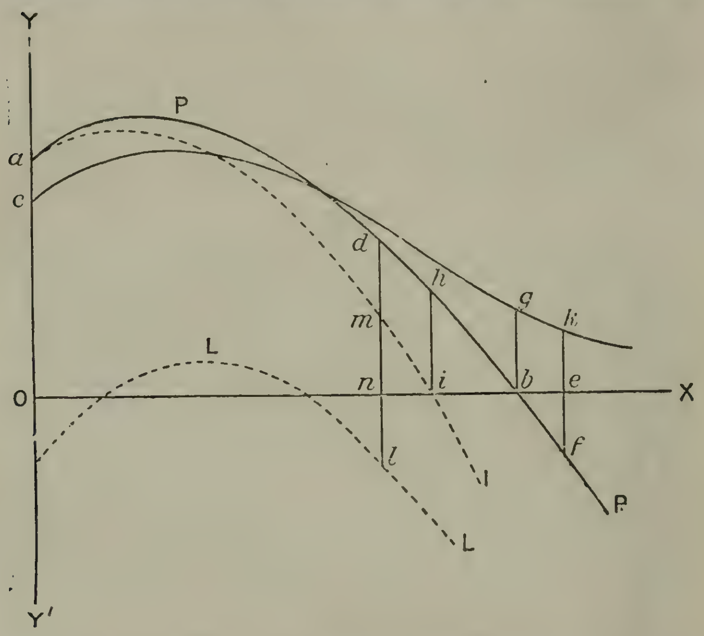
Note.

The argument in the more technical parts of this address, concerned with the determination of the length of the working day, may be conveniently summarised with the aid of the following figure. In order to avoid the complexities arising from the redistribution of labour between the industries of a country, suppose that only one industry exists. Measure units of time in the working day along O X, and units of money along O Y. Consider first the unbroken lines, which represent the influences governing employers. The curve P expresses the long-period variations with the length of the working day of the marginal value of a fixed quantity of labour: the opinion that these can be represented by a curve has been defended in the body of this address. If O n hours are worked daily, the daily value of labour and the wage will ultimately be O n d a; if O b hours are worked, this value and wage rises to O b a; if O c hours are worked, it falls to O b a — b e f. The meaning of the curve P will now be plain. The curve is supposed to rise in the first instance because increasing the daily hours of labour would at first raise the level of efficiency, and if it did not the larger wage would. But P must begin to fall at some point, and eventually cross O X, as is demonstrated in the body of the address. Actually, of course, P could not start at O Y, because a man when engaged for only a fraction of his time daily could not live on the proceeds of his work, but it has been so drawn in the figures to enable us to picture the value and wage of labour by the area between the curve P and the co-ordinates.

The curve c k represents the immediate variations of the marginal value of a fixed quantity of labour with the length of the working day on the assumption that the normal working day has been O b. Hence the value of the normal product of the last minute of the working day O b is b g. *Ex hypothesi* O b g c must equal O b a. If the working day is lengthened to O e the product will at first be augmented by b e k g, but finally by a gradual decline it will sink to O b a — b e f.

The influences guiding the operatives are expressed in the dotted lines, the meaning of which must now be explained. Draw any vertical line d l to the left of b. Then d n is the addition made in the long run to the money income of the operative when the O nth increment of time is added to the

working day. Let *d m* be the long-period value to the operative, when his income is O *n d a*, of the leisure destroyed by the addition of the O *n*th increment of time to the working day. The curve I is the locus of the point *m*. Evidently, starting at *a*, it will lie throughout its length below P, increasingly departing from P (because leisure is subject to the law of diminishing utility and the value of leisure rises with income), and cut O X to the left of *b*. Apart from the satisfaction or dissatisfaction of working, therefore, the far-sighted operative who took into account the value of leisure would choose a normal day O *i*, which is less than O *b* (the choice of far-sighted employers in combination). When the normal day is O *i* the marginal value of leisure to an operative with a wage O *i h a* would be *i h*, which equals the long-period marginal earnings attributable to the O *i*th increment of time in the working day. Now, let L indicate the long-



period values to the operative of the effects of different lengths of working day on the absolute satisfaction or dissatisfaction involved in the labour itself, L being otherwise interpreted as I, when units of money are measured along O Y′ as well as along O Y, and the parts of the curve below O X indicate the prices which would be paid to escape the dissatisfaction involved in working, and the parts above O X the money value of the satisfaction involved in working. As some of the time devoted to production will probably be pleasant to the operative when the length of working day is most favourable to his enjoyment of work, we may assume that L need not lie throughout its length below O X. Then the working day which perfectly wise operatives would choose would be O *n*, the point *n* being such that *n m* = *n l*, the attainment of which equation is the condition under which the operative's satisfaction is maximised. If, as is theoretically conceivable but practically impossible, L lay further above O X for the

abscissa O b than I lay below it, the length of day most advantageous to the operative would be greater than O b.

If normal hours are O n, the operative who lives for the day, and is aware that more work, measured by results, means proportionally more pay, may be expected to desire hours longer than O n for the following reasons. The product attributable to the O nth increment of working time is greater than $d\ n$, since $d\ n$ represents the gain resulting from the O nth increment of working time, less the loss occasioned by the reduction which will *ultimately* take place in the productivity of the operative's earlier hours in consequence of the addition of the O nth increment of time to the working day. For similar reasons the short-period or immediate value of leisure may be less than $d\ m$. Again, the money measure of the disutility of the O nth increment of working time is less than $n\ l$, because $n\ l$ measures the disutility of the last fraction of time worked, together with the disutility which results from the fact that the O nth increment of working time diminishes capacity in earlier hours to enjoy labour or sustain fatigue. It is, therefore, practically certain that the operative will experience a balance of gain from the working of the O nth unit of time, when wages, the value of leisure and the feeling involved in the work, are all taken into account, while effects on the gain or loss associated with the rest of the working day are ignored; and, further, it is practically certain that a balance of gain will continue to result directly from the work of the O nth unit of time if the working day be slightly increased, though this balance might be expected to contract. Hence we must conclude that operatives who are not alive to the reactions of long hours on efficiency and capacity to enjoy life and work will tend to choose a longer working day than is wise from their point of view. However, to repeat, they will not approve such long hours as employers who are equally blind to future reactions, because the latter, if purely self-interested, make no allowance for the disutility of labour to the operative or the utility to him of leisure.

In the event of progress in methods of production the new position of P would be such that the area enclosed between it and the co-ordinate axes would be increased. P in its new position might cut O X at b, but in all probability the new intersection with O X would be to the left of b. It is not likely to fall to the right of b, since improvements in the mechanical aids of labour seldom mean that work is rendered less exhausting. Even if the new curve P passed through b, the new position of I would practically mean its intersection with O X to the left of i because of the enhanced value of leisure. Further, L, though it might rise higher than before would probably descend sooner and at least as steeply. It is to be observed in addition that but for interest, rent, and heavy depreciation charges, industrial progress would bring about movements of P involving more considerable augmentation of the area contained between P and the co-ordinate axes. Improved education, apart from its effect on efficiency, would bring about a subsidence of the curve I, so that in its new position it would cut O X to the left of i. The effect wrought by progress on short-period forces need not be worked out in detail. The general conclusion is manifest that progress may be expected to be accompanied by a progressive curtailment of the working day.

The following Paper was then read:—

1. *The Influence of the Development of Urban Conditions on Public Welfare. By* A. H. Steel-Maitland.

In the introductory paragraph the limitations of the paper were defined. In Section II. a short description was given of the structure of a great English city of the present day, and the nature of the evolution from a

large factory town. In Section III. a more detailed description was given of casual labour, and of the industrial features peculiarly characteristic of such great cities which have become centres of exchange. Casual labour was described as closely connected, on the one hand, with the structural formation of the city, and, on the other hand, with certain other industrial problems—sweated labour among women and to a less degree with 'blind-alley' occupations for boys. A statement was made of the economic loss to the community caused by the casual character of such labour, but the lack of accurate data was emphasised. Following the description of the industrial effects, a *résumé* was given of certain vital statistics showing the effect on public health of town life in general, and of extreme congestion in great cities in particular. Mention was made of characteristics which make certain illnesses responsible for a peculiarly great economic loss. Among such illnesses phthisis is the principal. In connection with the effect on public health the varying rates of infant mortality was noticed, as also were such data as have been hitherto collected as regards the physical development of children in different surroundings. The section ended with a reference to the effects of special features in housing—block dwellings, furnished rooms, and the absence of open spaces.

The object of Sections IV. and V. was to prevent an exaggerated view being taken of the situation. In the former the present state of England was favourably compared to that on the Continent, so far as vital statistics are concerned. Emphasis was also laid on the vast improvement in the conditions obtaining sixty years ago. In the latter section the contributory influence of other causes of injury was discussed. While complete discrimination as regards their respective effects is neither possible nor, indeed, necessary, some instances were given showing how a remedy applied to one of the general nexus of causes may favourably affect the general result.

In the last section the inferences which can be drawn from the preceding questions were summed up, and an analysis was given of the various points at which effort should be directed.

Joint Meeting with Section E and Sub-section K (Agriculture).

FRIDAY, AUGUST 27.

The following Papers and Reports were read:—

1. *The Gold Coinage of British Columbia*, 1862. *By* J. Bonar, *LL.D.*

The episode of a gold coinage in British Columbia is of more than local importance. The popular accounts of it are not wholly confirmed by the official correspondence. The issue of these pieces was one out of several expedients thought likely to relieve the inevitable embarrassments of large discoveries of gold. They were to be issued by the Assay Office at New Westminster. The doubtful experiment was stopped at the outset, not by the Home authorities, but by difficulties on the spot.

Since 1862 the *industrial* situation has changed; the centre of gold-production is elsewhere; and British Columbia produces much besides gold. The *political* situation has also been altered by the entrance of British Columbia into the Confederation in 1871. A gold currency could not be provincial.

---

2. *Small Holdings and Co-operation. By* C. R. Fay, *M.A., D.Sc.*

The importance of small holdings in England has been growing during the last few years, and as the result of the legislation of 1907 there is a

definite small holdings movement, welcome to some and unwelcome to others. Causes, immediate and distant, may be found for this movement; and among the latter sort must be reckoned the trend of international agriculture, especially in North and South America, which has a tendency to turn English agriculture into lines not unsuited to small-scale farming. Small holders, however, have many difficulties to overcome in the matter of capital, technical knowledge, organised marketing and a suitable environment. It is suggested in this paper that co-operation is essential to the success of small holdings on any considerable scale; and the suggestion seems supported by the experience of Western Europe. Continental experience also indicates the varying power of co-operation, the comparative ease of co-operative purchase and co-operative credit and the serious difficulties of co-operative sale. Small holdings will have to justify themselves as a business success first and foremost; but if they can do this they can claim additional merit as factors in the revival of a sound rural population.

---

3. *Is Increasing Utility possible?* *By* W. R. Scott, *M.A.*, *Litt.D.*, *D.Phil.*

When the nature of Utility was first made the subject of a special examination by Gossen, Jennings, and Jevons, the conclusions reached were based upon Hedonistic assumptions. Professor Marshall, however, in 1893, expressly defines 'the pleasure' obtained as the result of action 'as every good for which a man strives.' But the entanglement of many economists in Hedonistic presuppositions makes it necessary to define the object of desire in light of recent philosophical results. A want of clearness on this point often leads to confusion, as for instance in the reasoning by which Weiser brings the collector of books or pictures under the law of Diminishing Utility.

Desire is, in fact, a practical problem, the solution of which involves satisfaction, which is measurable. The progressive attainment of satisfaction need not, however, be conceived as necessarily subject to continuous diminution. This is not so in some desires, in which case there is Increasing Utility. Are there any economic desires to be placed in this class? An analysis of the satisfactions obtained by the philatelist in the reconstruction of plates of stamps which yield increasing not diminishing Utility. This result can be verified by his Demand Schedule. The difficulty whether any change in character or taste is supposed was discussed, also that raised by Marshall regarding 'a certain special want'; the existence of Increasing Utility was confirmed by reference to the 'Amherst Caxtons,' and the acquisition of a 'controlling interest' in a company.

Where Increasing Utility exists there is a reference to the conception of completeness, and sometimes to a monopoly in consumption. The conditions involved are often the reverse of those in Diminishing Utility, where the total quantity of a commodity which a person would desire is very small in relation to the amount offered for sale. In Increasing Utility, on the contrary, the commodities which are grouped together by the idea of completeness, and which with other elements form the object of desire, are keenly sought after, and exist only in small quantities.

If Increased Utility be admitted the theory of Economics becomes more symmetrical, and such admission would have practical results in relation to taxation.

---

4. *Interim Report on the Amount of Gold Coinage in Circulation in the United Kingdom.*—See Reports, p. 208.

---

5. *Interim Report on the Amount and Distribution of Income below the Income-tax Exemption Limit.*

MONDAY, AUGUST 30.

The following Papers were read:—

1. *The Policy of Preferential Duties.* *By* Archibald B. Clark, *M.A.*

The policy of import duties differentiating in favour of trade between the different parts of the British Empire as against trade with foreign countries, has been advocated partly on economic and partly on political grounds.

The object of this paper was to inquire whether, viewed from either standpoint, the policy is in the long run likely to benefit Great Britain, the self-governing colonies, or the Empire as a whole.

Economic Standpoint.—(1) The self-governing colonies are clearly not at present prepared to take any serious step in the direction of free trade within the Empire. (2) Nor would they be likely to appreciate the adoption by the United Kingdom of a policy of all-round protection, colonial products merely receiving at British ports preferential treatment equivalent to that accorded to British goods at colonial ports. (3) On the other hand, any scheme such as that under which the United Kingdom is asked to tax imports from foreign countries, and to admit colonial produce free of duty as at present—while the colonies continue to tax her produce to an extent sufficient to protect their own industries, merely granting a preference to British as against foreign goods—is clearly indefensible.

(*a*) It is unlikely to increase materially Great Britain's export trade to the colonies. This is shown by considering the nature of the foreign trade of the self-governing colonies, and is illustrated by an examination of the working of the Canadian preference.

(*b*) It would inflict a heavy blow on Great Britain's export trade to foreign countries, compared with which that to the self-governing colonies is insignificant. Not only would Great Britain lose the benefit of the 'most favoured nation' treatment, but the taxation of food (which would inevitably be followed by the taxation of raw materials also) would, by raising its price, raise the cost of production of manufactured goods, and would thus handicap Great Britain in neutral markets. Moreover, the poorer the family the larger the proportion of the income spent on food, and thus the burden of a tax on food would fall most heavily on the poorest.

Even then, if we concede what is open to question, viz., that the stimulus thus given to colonial producers would in the long run enable them to meet the demand of Great Britain without any rise in price, still in the interval irreparable mischief would be done. If the food-producing colonies have any faith in the attainment of this ideal of a self-sufficing Empire, and really desire to hasten its advent, an expedient surely less ruinous to the Empire as a whole would be found in the granting by them of bounties on exports of agricultural produce.

But from the economic standpoint the whole policy of preferential duties, as an ideal, is unsound. It can only be defended as a half-way house, or a step in the direction of free trade. A real reduction of protective duties in favour of the United Kingdom would no doubt benefit not only the Mother Country, but Canada herself. By removing the leading strings of protection to some extent, it would so far set free Canada's productive powers to follow their natural channels. But in that case a general reduction of duties all round would benefit Canada, and in the long run the United Kingdom also, still more.

Political Standpoint.—The policy of preferential trading is advocated by many on the ground that the present dependence of the United Kingdom on foreign countries for her food supplies constitutes a grave Imperial danger, but this dependence is actually in some respects a source of strength. It secures to Great Britain friends in need, for the countries that supply her wants are bound to her by the tie of mutual interest. The United States, for example, would be little likely to stand by and see food supplies for Great Britain made 'contraband of war.' It thus appears that a self-sufficing Empire is no more attractive as a political than as an economic ideal.

Finally, the policy of preferential trading relations is advocated as 'tightening the ties'—reinforcing the existing bonds of sentiment and blood relationship by a sense of economic unity, or common material interest throughout the Empire. But the policy of Imperial preference, once adopted by Great Britain, could not be confined to food stuffs. It must inevitably extend and grow till it became an all-round system of high protection; and there is grave reason to doubt whether an Imperial preferential tariff could be arranged without bringing into dangerous conflict the diverse and often opposing interests of the different States of the Empire. The present Canadian preference, as the voluntary gift of a free people, stands on quite a different footing. Great Britain's hold on the colonies is not conditional on her adoption of protection. The bonds of Empire are other and stronger than those of mere commercial interest.

---

2. *The Insufficiency of a National Basis for Economic Organisation.* *By* Professor EDWIN CANNAN, *M.A., LL.D.*

Prevailing opinion assumes that the nation is and must be the unit of economic organisation, whether the organisation is based on individualist or socialist principles. There is some difficulty in deciding what a nation is, but it is generally taken to mean the people of any area with common customs-duties. Socialists at the present time usually propose to take each of these nations as the society or community which should own the means of production. It may easily be shown that this would lead them into insuperable difficulties. Either each nation must be self-sufficient as regards capital, or borrowing and lending must be established between them. The former alternative would delay economic progress enormously by preventing the capital accumulated in the old settled areas from being applied to the development of the new; the other alternative would involve the abandonment of the fundamental socialist tenet of the illegitimacy of interest, and would also end in drastic restrictions on migration from the poorer areas into the richer. To the question whether the socialist may not reasonably regard national organisation as a forward step in the progress towards mundane organisation the answer is in the negative. The proposed national organisation, supposing it turned out successful inside each nation, would only have the effect of enlarging the surplus available for warfare.

To the individualist the national unit is in reality equally unsatisfactory. The socialist can at any rate conceive his nation as a sort of family closed from outside intrusion; but this is scarcely possible for an individualist who thinks that men should be free to move about and acquire property where they will. To him the material welfare of the nation can convey no very definite meaning. The struggle which is carried on between the different nations cannot be regarded as a beneficent competition tending to the good of the whole number, like the competition carried on between individuals within a civilised country, since it is anarchic, instead of being directed into beneficent channels by institutions and laws

established, maintained, and from time to time modified, for that very purpose.

The conclusion is that practical persons should look forward to mundane organisation, and that exponents of economic theory should be much more careful than they have been not to confuse economic society with a single nation.

---

3. *Local Taxation in Manitoba.* By W. Manahan, *Ph.D.*

Although dealing with local taxation, the author thought it might be well to note that the revenue of the Dominion for 1908 was 96 million dollars, the largest in its history. Of this amount about 58 millions came from customs, and nearly 16 millions from excise. The remainder of the revenue is derived from a number of miscellaneous items, and cannot be termed taxes.

In the Province of Manitoba for last year the revenue was $2,900,000, also the largest in its history. Of this nearly $900,000 is paid by the Dominion as annual subsidy and interest on school lands. Telephone rentals and sale of provincial lands amount to over $1,000,000. Thus there is less than $1,000,000 of the revenue coming from taxation. The court fees $45,000, liquor licences $100,000, the corporation and railway taxes $190,000, and succession duties $42,000 are practically the only items which can be called taxes.

In the City of Winnipeg for last year there was a direct tax on real property of 15 mills on the dollar. This amounted to $1,800,000. This is the general municipal and school tax. Besides this $700,000 was levied as special assessments for local improvements. For the present year land is assessed at its full value, and buildings at two-thirds of their value. The value of a building is the value that the land is thereby increased. There is also a tax of 6·2 per cent. of the annual rental value of premises used in business or in professions. This is known as the business assessment, and amounts for the current year to over $200,000. The business assessment does not include those who pay a licence to the City for carrying on their business. Licence fees for the past year were $84,000. The Electric Railway Company paid $85,000 to the city last year, but this is by special agreement made at the time the railway was built. These are the only items of taxes in the city's revenue, which last year was $2,500,000.

TUESDAY, AUGUST 31.

The following Papers were read:—

1. *Phases of Canadian Labour Conditions.* By Adam Shortt.

Labour conditions in Canada reflect world movements, but embody special features peculiar to Canadian circumstances. Among the special features are the great new areas of agricultural land and other natural resources, the development of which is only now being undertaken on a large scale. Connected with this is the incoming of thousands of new settlers and of millions of foreign capital. Labour in Canada is conditioned also by special features of seasonal employment, changing markets, and the highly specialised conditions of new settlements with a limited range of employments, and the carrying on of great undertakings such as the building of railways, the establishing of hydraulic plants and electric generators, and the building of mills of various kinds out in the wilderness and away from the normal conditions of life and supplies.

Individuals, corporations, and governments, national, provincial, and

municipal, are freely borrowing foreign capital for investment, or at least expenditure, in the country. This capital, together with the native supplies, furnishes an immense wage-fund, as well as a fund for supplies, which together render Canada an exceptionally good market for labour and supplies. The prosperity due to this investment is undisturbed by thoughts of future repayment or of interest in the meantime. For some time there has been every stimulus to expansion. Increasing wages and profits lead to increased prices, and increased prices mean increased cost of living, which, in turn, is justification for a further increase in wages and a still further increase in prices.

The expansion of Canadian settlement means the building of thousands of miles of railroads through the wilderness, the construction of hundreds of towns, and thousands of farm houses, with all that these involve in the way of labour and supplies, the work of transportation, and the stimulus to the centres of production in older Canada. So long as foreign capital continues to flow in this condition prosperity will accompany its expenditure in the country, for the latent resources of Canada are very great. It means, however, that Canadian expansion is very largely conditioned by the financial circumstances of the outside world.

Assuming the permanency of outside conditions, and regarding only the increasing prosperity of the country, as marked by the increase in wages and prices, the question arises, Is this prosperity real, or is the greater part of it only apparent? How far is the increase in wages neutralised by the increase in the cost of living and the increase in prices offset by an increase in the cost of production? Also, are there not considerable sections of the community who, with little increase in income, have to face a large increase in the cost of living? The foundation on which an answer to these questions must be sought is the fact that there are but two directions in which a community supplying the greater part of its own wants may increase its real wealth or elevate the standard of living. One is the inducing of Nature to contribute more from her stores per unit of persuasive effort; the other is by economising human time and effort in working up the products and forces of Nature into articles for the supply of wants or the rendering of services. If the benefits from these sources are fairly distributed there will be a real increase, not only in the community's wealth, but in the standard of comfort. Under such conditions incomes might increase without increasing prices, or prices might be lowered without diminishing incomes. Where, however, wages and prices both rise in much the same proportion there is little real advantage, and what there is is probably drawn from those classes in the community who can neither increase their incomes nor prevent others from increasing prices and wages.

A survey of Canadian conditions shows that all three phases of economic adjustment are presented. We find in certain cases an increase of natural products per unit of labour, and an increase of finished product in proportion to cost in capital, time, and effort. But we find also a purely nominal increase in values, as in the reciprocal rise in wages and labour wherein one neutralises the other to a very large extent, though the balance is not always equally maintained, some gaining while others lose.

Considerable specific light is thrown on the subject of the real and nominal betterment of labour in Canada by a couple of tables of prices and wages prepared for this Paper by Mr. R. H. Coates, B.A., of the Department of Labour, Ottawa. The table of prices covers such fundamental elements in the cost of living as rent, fuel, and the chief articles of food in representative centres throughout the Dominion, and for the years 1899 and 1909. The table of wages covers chiefly the building trades and phases of unskilled labour in the same centres and for the same years. These tables indicate that in the upward struggle between wages and

prices the wage-earners, obviously largely through the aid of their unions, have been rather more than able to hold their own. Nevertheless, whether in virtue of natural conditions or through the control of markets, prices have been kept closely in the wake of the upward movement of wages. With prosperous times, based on the conditions already outlined, the vendors of both labour and goods have a vital command on their respective markets. As a result, an increase in wages has been taken as a good reason for an increase in prices, and an increase in prices as a still better reason for a rise in wages. But while wages and prices thus pursued each other in an ascending spiral, the miscellaneous body of citizens, who have no direct access to the industrial and commercial wheel of fortune, have stood helplessly by, anxiously watching the ascent of the cost of living. Some of them have occasionally managed to secure an increase in income, though in a very irregular and uneconomic manner. From the enhanced prices paid by the non-competitive classes for their diminished supplies there have been chiefly furnished what advantages the wage-earners and profit-takers have obtained since they have been unable to exploit each other. Among these unfortunate bystanders are such classes as the general body of clerical assistants, not directly connected with trade or industry, and commonly paid by salary, the general body of public officials so far as not included in the former class, the non-commercial, professional, or semi-professional classes, and also those who are dependent upon pensions, annuities, or other fixed incomes. In any case it is evident that, though the business of the country has greatly increased, and though speculators in real estate and other natural resources and those who are able to conduct business on a large scale have been able to make more or less extensive fortunes, yet the great apparent improvement in the lot of the wage-earner, the small tradesman and producer, and the general non-commercial element is far from being so great as it appears on the surface. Indeed, their chief advantage lies in the fact that they are receiving steady employment, whereas in less prosperous days their employment was more uncertain and in consequence their standard of living sometimes lower.

Referring more closely to Mr. Coates's tables, we find that, omitting some extreme quotations, meat, potatoes, eggs, butter, milk, fuel, and house rent have increased in price from 25 to 50 per cent. within the past decade; also that the wages of the trades covered by the table have increased from 25 to 60 per cent. On the other hand, the prices of groceries have increased but slightly or not at all. When we follow up these conditions beyond the range of Mr. Coates's tables, to include dry goods, hardware, lumber, and other raw materials, we find, as a rule, that wherever the articles are imported or made up under conditions of manufacture on a large scale, prices have increased very moderately; whereas where the articles involve a considerable element of Canadian labour, not under factory organisation, prices have risen very greatly; in fact, the prices reflect the increase in the wages of the labour employed on them and the profits of the middlemen who handled them.

The general outcome of this line of investigation is that such essential elements in the cost of living as native food products, fuel, housing, clothing made to order, and all forms of service very largely owe their increased cost to a rise in wages, which the producers and dealers connected with them have been able to translate into increased prices. On the other hand, the slight increase in groceries and foreign foods would indicate a more stable wage scale abroad, while the moderate increase in the price of articles produced in Canadian factories working on a large scale indicates that the increased wages paid to the employees have been partly offset by economies in production and the obtaining of profits on a lower rate per unit, but on a larger scale.

One conclusion from the survey is that there is no real advantage in

the blind duel between wages and prices. Each seems to be gaining a victory, but on both sides it is practically barren, while, as is usual in such cases, many non-combatants are suffering innocently and unnecessarily.

But the issue is not merely a negative one. There is a positive and serious disadvantage in this needless raising of wages and prices. We cannot expect steady employment and ready sales to continue without interruption. In times of continuous employment it may appear of little moment whether the wage-earner receives a lower wage which buys cheaper goods or a higher wage which buys a like amount of dearer goods. In times of slack work, however, high prices for the necessaries of life become a serious matter for a wage-earner without wages. In accordance with the general practice of trade unions, union labourers will not be inclined to accept a reduction in wages even when that might partly save the situation; hence the distress from slack employment is likely to be augmented by numerous disastrous strikes against a falling market. Similarly in the case of manufacturers and general employers, in times of depression high prices invite ruin. They stagnate trade on the one hand, while on the other they attract competition from without as metal draws the lightning. Yet employers, rather than reduce prices, will clamour for a higher protective tariff, in order that within its shelter they may form combinations to restrict production and save prices as long as possible.

Altogether, these much vaunted symptoms of prosperity, high wages and high prices, are quite unnecessary elements of true welfare and business success; while in periods of temporary depression or declining trade they seriously impede readjustment, and by the disorders they entail may easily convert a moderate depression into a severe crisis, demoralising trade and credit and resulting in a prolonged stagnation.

---

2. *Recent Progress in the United Kingdom as shown by Statistics.* *By* Professor A. L. Bowley, *M.A.*

---

3. *Some Economic Results of Specialist Wheat Production for Export.* *By* Professor James Mavor.

The author described the mechanism of the organisation of agricultural industrial and commercial capital by means of which wheat is moved from the place of production to the place of consumption, and discussed the effect of the process upon the economical situation of the farmer. This process greatly increases the velocity of the return of his agricultural capital; but it involves for him a certain dependence upon the mechanism. Thus, it may be an act of wisdom for him in order to recover his independence to engage in mixed farming, or at all events to modify his specialisation in order to avoid the risks which specialist production necessarily involves.

---

4. *The Economic Efficiency of the Chinese.* *By* N. C. Home, *B.A.*, *LL.B.*

The possible importance of the investigation of the economic characteristics of different peoples, and in particular of the Chinese people, was discussed.

The Chinese people is mainly a race of petty farmers, characterised by independence of Governmental control and submission to the head of the family. They can develop physical energy on a minimum food supply. Their daily lives are influenced by the Confucian rules of conduct.

The Chinese as mechanics show a high average of proficiency, but fail to do work of the first class.

In commerce, trade, and business generally they have a high reputation for commercial integrity, but there are limitations within which such reputation ought to be accepted.

They are usually at their worst as officials.

They fail to appreciate the obligations incidental to the administration of trusts.

The scale of expenditure of the Chinese out of their own country is a rising one, and there are reasons sometimes operating to cause them to maintain a minimum scale.

The objections taken to Chinese immigration, and the arguments in its favour, and the problematical nature of the whole question, were referred to.

Section G.—ENGINEERING.

President of the Section:
Sir W. H. White, K.C.B., Sc.D., LL.D., F.R.S.

THURSDAY, AUGUST 26.

The following Paper was read:—

Hydroplanes or Skimmers.[1] *By* Sir John Thornycroft, *F.R.S.*

The President then delivered the following Address:—

On the present occasion, when the meetings of the British Association for the Advancement of Science are held in the heart of this great Dominion, it is natural that the proceedings of Section G (Engineering) should be largely concerned with the consideration of great engineering enterprises by means of which the resources of Canada have been and are being developed and the needs of its rapidly increasing population met. It will not be inappropriate, therefore, if the Presidential Address is mainly devoted to an illustration of the close connection which exists between the work of civil engineers and the foundation as well as the development of British Colonies and Dominions beyond the seas.

British colonies and possessions have started from the sea-front and have gradually pushed inland. Apart from maritime enterprise, therefore, and the possession of shipping, the British Empire could never have been created. An old English toast, once familiar but which has of late years unfortunately fallen into comparative desuetude, wished success to 'Ships, Colonies, and Commerce.' A great truth lies behind the phrase: these three interests are interdependent, and their prosperity means much for both the Mother Country and its offspring. As colonies have been multiplied, their resources developed, and their populations increased, over-sea commerce between them and the Mother Country has been enlarged; greater demands have been made upon shipping for the over-sea transport of passengers, produce, and manufactures; there has been a growing necessity for free and uninterrupted communication between widely scattered portions of the Empire, the maintenance of which has depended primarily and still depends on the possession of a supreme war-fleet, under whose protection peaceful operations of the mercantile marine can proceed in safety, unchecked by foreign interference, but ever ready to meet foreign competition.

Now that our colonies have become the homes of new nations it is as true as ever that the maintenance of British supremacy at sea in both the mercantile marine and the war-fleet is essential to the continued existence

[1] Published in *Engineering*.

and prosperity of the Empire. The trackless ocean supplies the cheapest and most convenient means of transport and intercommunication; continuous improvements in shipbuilding and marine engineering have bridged distances and given to sea-passages a regularity and certainty formerly unknown. It is a literal fact that in the British Empire the 'seas but join the nations they divide.' Every triumph of engineering draws closer the links which bind together its several parts. Greater facilities for frequent and rapid interchange of information of what is happening in all sections of the Empire and of knowing each other better should lead, and has led, to increased sympathy and a fuller realisation of common interest in all that affects the well-being of the Empire. Within the last few years the events of the Boer War have given remarkable proofs of the practical interest of the colonies in Imperial concerns and their readiness to share its burdens. The present year will always be remembered as that in which generous offers of assistance from the colonies in the task of strengthening the Royal Navy at a critical period have led to a conference whose labours should produce important practical results and make our future secure. Organised co-operation between the Mother Country and the Dominions beyond the seas in the maintenance of an Imperial Navy adequate for the protection of vital interests is essential to that security; and, at last, there is a prospect that this end will be attained.

While claiming for the shipbuilder and marine engineer an important place in the creation and maintenance of the Empire, it is recognised that the work of other branches of civil engineering has been equally important. The profession of the civil engineer was described in the Charter granted to the parent institution in 1828 as 'the art of directing the Great Sources of Power in Nature for the use and convenience of man; as the means of production and of traffic in states both for internal and external trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation, and docks, for internal intercourse and exchange; and in the construction of ports, harbours, moles, breakwaters, and lighthouses; and in the art of navigation by artificial power for the purposes of commerce; and in the construction and adaptation of machinery and in the drainage of cities and towns.' Since this description was penned there have been great and unforeseen developments in many directions, including those relating to improvements in the use of steam, the generation and practical applications of electrical power, the manufacture and extended employment of steel. The main ideas expressed eighty years ago, however, still remain applicable to the beneficent work of the civil engineer. His skill and enterprise, backed by adequate financial provision, are continuously being applied to improve and extend means of production, internal and external means of communication, inland and over-sea navigation, the use of mechanical power and appliances, the acceleration and cheapening of transport, the development and utilisation of natural resources, and the direction of the sources of power in nature for the use and convenience of man. One of the chief fields of engineering operations at the present time is to be found in the Dominion of Canada, whose governing authorities have appreciated the fact that bold enterprise and generous financial provision for the execution of great engineering works are essential to the progress and prosperity of the country. Its vast extent, its magnificent lakes and rivers, its agricultural and mineral riches, its forests, its unrivalled water power, and many other potential sources of future wealth and progress furnish exceptional incentives and opportunities to the engineer. From an early period in the history of Canada this fact has been realised, and attempts have been made to utilise natural advantages; while the same policy has been energetically adopted since the Dominion was established forty-two years ago. It is impossible in this Address even to enumerate the great engineering works which have been accomplished or are in process

of execution; and it might be thought impertinent if the attempt were made by one who has only an outside knowledge of the facts. On the other hand, it may be of interest to illustrate by means of Canadian examples the truth of the general statement that civil engineering has exercised and must continue to exercise great influence upon the well-being and development of the British Empire.

By the kindness of the High Commissioner of Canada, Lord Strathcona—who has himself done so much for the development of the Dominion, including a great part in the construction of the Canadian Pacific Railway—the writer has been favoured with official reports and statistics bearing on the subject. These have been freely used in the statement which follows.

The subject is so extensive and the time available for this Address so short that it will be necessary to omit detailed reference to important applications of engineering which are necessarily made, under modern conditions, in all great centres of population. Amongst these may be mentioned building construction, sanitation, water supply, heating, lighting, telegraphy, telephony, tramways, electric generating stations and their plant, and gas manufacture. No attempt will be made to deal with the important assistance given by engineers to the operations of agriculture, mining, and manufacture, or to the utilisation of the splendid forests of the Dominion: although the demands for machinery and mechanical power is in these respects exceptionally great, owing to the sparseness of the population and the magnitude of the work to be done. Notwithstanding the large immigration and rapid increase of population, these demands will certainly continue and will probably become greater as the area under cultivation is increased, as manufactures are developed, and the natural resources of the country more largely utilised. The example of the United States places this anticipation beyond doubt, and demonstrates the great part which the engineer must continue to play in the development of Canada.

Even when the limitations described have been imposed upon the scope of this Address the field to be traversed is a wide one; and without further preface an endeavour will be made to describe a few of the most important services which the engineer has already rendered to the Dominion and will render in the immediate future.

Railways.

It has well been said that the great problem of to-day in Canada is that of providing ample and cheap transport for her agricultural, mineral, and forest products from the interior to the sea, and so to the markets of the world. Important as inland navigation may be as an aid to this enterprise, it cannot possibly compare with railway development in actual and potential results. Apart from that development the one united Dominion must have remained a dream; thanks to the rapid and efficient intercommunication furnished by railways, widely scattered provinces are knit together in friendly and helpful union, literally by 'bonds of steel' which stretch from the Atlantic to the Pacific, and reach farther and farther north each year. Regions which would otherwise have remained inaccessible and unproductive have been turned into new provinces, whose fertility and future development it is not easy to forecast, and practically impossible to exaggerate.

In this department successive administrations (both Federal and provincial) have realised the facts and possibilities of the position, and have given substantial assistance to private enterprise in the execution of great engineering works. Progress in railway development has been remarkable since Federation was accomplished forty-two years ago. During the preceding thirty years the total railway mileage in operation had been raised to 2,278 miles; in 1887 it was 12,184 miles; in 1897, 16,550 miles; in 1907, 22,452 miles. The number of miles of railway actually under construction in

1907 was officially estimated at 3,000, exclusive of lines projected but not yet under contract. In 1906, when the lines in operation were 21,353, it was estimated by competent authorities that the railways under construction, and projects for extensions likely to be carried into effect in the immediate future, reached a total of at least 10,000 miles, while probable further extensions of about 3,500 miles were under consideration. Further, it was estimated that the capital expenditure required to complete these schemes would be about 60 millions sterling. These figures may need amendment, but there are others representing ascertained facts which equally well illustrate the magnitude of the railway interests of the Dominion.[1] The total capital invested in Canadian railways in 1907 was officially reported to be about 234,390,000*l.*; the aid given to railways up to that date by Dominion and Provincial Governments, and by municipalities, considerably exceeded 36,000,000*l.* sterling in money; the land grants from the Dominion Government approached 32 million acres, while the Provincial Governments of Quebec, British Columbia, New Brunswick, and Nova Scotia had granted about 20½ million acres. The Governments have also guaranteed the bonds of railway companies to the extent of many millions of dollars. The capitalisation per mile of railway lines owned by the Governments (amounting to 1,890 miles) is reported as being 11,400*l.*; this is practically the same amount as that for Indian railways, that for the United States being 13,600*l.*, and for New South Wales and Victoria about 12,600*l.* For British railways the figure given is 54,700*l.* per mile. The freight carried by Canadian railways in 1907 amounted to nearly 63,900,000 tons (of 2,000 lb.), which included about 14,000,000 tons of coal and coke, nearly 4,500,000 tons of ores and minerals, 10,250,000 tons of lumber and other forest products, nearly 7,900,000 tons of manufactures, and 2,309,000 tons of merchandise. In 1875, when 4,800 miles of railway were in operation, the corresponding freight-tonnage was 5,670,000 tons; so that while the length of railway increased nearly 4.7 times, the tonnage increased nearly 11.3 times. During the same period passengers increased from 5,190,000 to 32,137,000. For twenty-eight railways making returns the average revenue per passenger per mile was 2.232 cents, and for the four principal railways was 2.07 cents. For freight fifty-nine railways showed an average rate of 2.328 cents per ton-mile; and for the five principal railways it was .702 cent per ton-mile. The average distance travelled by a passenger was 64 miles, the corresponding figure for the United States being 30.3 miles. The average distance a ton of freight was hauled was 183 miles, as against 132 miles for the United States. In Canada, as the official reporter remarks, there is a small amount of suburban railway traffic and a low density of population. The following table is taken from the official Canadian Railway Statistics for 1907:—

—	For each mile of Railway.	
	Population.	Square miles of Territory.
United States	381	13.61
United Kingdom	1,821	5.29
France	1,590	8.46
New South Wales	686	146.09
New Zealand	358	43.42
Victoria	360	25.89
India	10,119	61.09
Canada	289	161.8

[1] Most of these statistics are taken from the valuable Report for 1907, presented to the Minister of Railways and Canals by Mr. Butler, Deputy Minister and Chief Engineer of the Department.

Canada has therefore the highest mileage measured against population, and the lowest against territory.

The earliest great railway system of Canada, the Grand Trunk, had its beginnings in 1845; in 1907 it was working about 3,600 miles within the Dominion. In association with the Government it is now engaged on the construction of the Grand Trunk Pacific Line, which will cross the Continent wholly in Canadian territory, and have a length of 3,600 miles, exclusive of branches.

The story of the Canadian Pacific Railway is well known, and need not be repeated; the influence which its existence and working have had upon the prosperity of the Dominion has been enormous and beneficial since its opening in 1885, and experience of its effect has led to the promotion of other Trans-Continental lines. In June 1907 the total length in operation was nearly 9,000 miles, and the company owned in addition great lines of steamships employed on Atlantic and Pacific services.

The Canadian Northern Railway system represents one of the most striking examples of recent railway development in the Dominion. In 1907 it was working nearly 2,600 miles in the North-Western provinces, about 150 miles in Ontario, 500 miles in the Province of Quebec, and 430 miles in Nova Scotia and Cape Breton, making a total of nearly 3,700 miles. In 1908 its mileage on the main system was reported to have increased to nearly 3,400 miles, and the total length in operation had become 4,800 miles. The North-Western Provinces have given substantial assistance to this great system, and its promoters are said to aim at a complete Trans-Continental route, as well as the development of railway communication to Hudson's Bay and the establishment of a line of steamships therefrom to Great Britain.

Besides these three great railway organisations, which in 1907 controlled about 75 per cent. of the mileage in operation, there are a large number of smaller companies, making up a total of about 80. Their total earnings in 1907 amounted to 29,350,000*l.*, the total working expenses being 20,750,000*l.* Earnings from freight service were (in round figures) 19,000,000*l.*; from passenger service 7,837,000*l.*; from express services 655,000*l.*; from mails 325,000*l.*, the balance coming from miscellaneous items. The total number of persons employed by the railways was 124,000; their salaries and wages amounted to 11,750,000*l.* It was officially estimated that if to the railway employés were added persons employed in factories for rolling stock and railway materials, as well as those engaged in the casual service and shipping, with an allowance for their families, 'quite 25 per cent. of the population win their daily bread from the carrying trade' of the Dominion.

The equipment of the Canadian railways in 1907 included 3,504 locomotives, 3,642 passenger cars, and 113,514 freight cars. In the opinion of the official reporter on railway statistics, based chiefly on a comparison of the proportion of rolling stock to mileage in Canada and the United States, a considerable increase of rolling stock is required, and there is a possibility of greater efficiency being obtained in the utilisation of existing freight cars. The manufacturing resources of the Dominion are declared to be fully capable of meeting all requirements, as in 1907 they produced 227 locomotives, 397 passenger cars, and 13,350 freight cars. A reduction of grades and curvatures has been carried out on the principal railways in recent years, and this has permitted the hauling of heavier loads. It is estimated that in 1907 the average earnings per ton of freight hauled were \$1.472, and the average earnings per passenger carried were \$1.219. The earnings per train mile were \$1.953, and the working expenses \$1.381. The total earnings per mile of railway were \$6,535.64, and the working expenses were \$4,620.9. The working expenses were divided as follows in the official report:—

Maintenance of way and structures	20.13 per cent.
„ equipment	20.88 „
Conducting transportation	55.25 „
General expenses	3.74 „

Allowing two cords of wood fuel to be equal to one ton, 5,609,000 tons of fuel—of which 5,578,000 tons were coal—were consumed by Canadian railway locomotives in 1907 in running 100,155,000 miles. The total cost was about 3,027,500*l*., equal to 14.59 per cent. of the working expenses.

From this brief summary of facts some idea may be gained of the rapid development of Canadian railways, their immense capital value and traffic, and the remarkable influence they have had upon the progress and population of the Dominion. It is a matter for satisfaction that British capital and engineering skill have contributed in no small measure to produce this development, and it may be hoped that in the future they may render even greater service.

Inland Navigation.

The most important system of inland navigation which Canada possesses is primarily due to the existence of the Great Lakes and the St. Lawrence River ; but the utilisation of these natural advantages and the construction of a continuous navigable channel from the sea to the head of Lake Superior is due to the work of engineers. The importance of such a navigable waterway leading to the heart of the Dominion was recognised long ago by the Government. The first canal is said to have been opened in 1821, and from that time onwards the canal system has been developed, but the greatest progress has been made during the last forty years under successive Administrations. Up to March 31, 1907, the capital expenditure on Canadian canals, exclusive of outlay by the Imperial Government, has approached 18,350,000*l*. sterling, of which more than ten millions have been spent on enlargements. Besides minor canal systems, many of which are important, a great 'trunk system' of water-transit has been created from Montreal to Port Arthur, at the head of Lake Superior, this all-water route being nearly 1,300 miles in length, having a minimum depth of water of 14 feet and effecting a total vertical rise of about 600 feet from tidal water in the St. Lawrence to Lake Superior. In order to effect this rise forty-nine locks are provided, most of which are 270 feet long and 45 feet wide, enabling vessels 255 feet long to be accommodated. Out of the total length of more than 1,200 miles only $73\frac{1}{2}$ miles consist of artificial channels. The Welland Canal, connecting Lakes Erie and Ontario—with a total rise from lake to lake of 327 feet, effected in twenty-five locks—is $26\frac{3}{4}$ miles long. This canal dates from 1824 ; its enlargement to present dimensions was begun in 1872, and occupied fifteen years ; the total expenditure on the canal has been nearly five and a-half millions sterling. Another important section of the waterway is the Sault Ste. Marie Canal—about 6,000 feet in length and from 142 to 150 feet wide between the pier-ends, with a lock 900 feet long, 60 feet wide, having $20\frac{1}{4}$ feet of water over the sills. The difference of level between Lakes Superior and Huron is 18 feet. Commenced in 1888, the Sault Ste. Marie Canal was opened for traffic in 1895, the cost being about 930,000*l*. Like its predecessor on the United States side of St. Mary's River—the so-called 'Soo' Canal affords *free passage* for the ships of both countries. In 1898 about two and three-quarter millions represented the tonnage of vessels passing through the Canadian Canal, and of this total about 403,000 tons was in Canadian vessels. In 1907 the total tonnage had risen to 12,176,000 tons, of which 2,288,000 was in Canadian vessels. The Soulanges Canal is fourteen miles long, with a rise of 84 feet effected in four locks. Commenced in 1892, it was opened for traffic in 1899, and cost nearly 1,400,000*l*. The Lachine Canal was commenced in 1821, enlarged in 1843 and 1873, and, as

completed in 1901, is $8\frac{1}{2}$ miles long, has 45 feet rise, effected in five locks, and has cost from first to last about 2,300,000*l*.

In the construction of this great waterway many difficult engineering problems have been solved, and every modern improvement has been introduced; electricity has been utilised in its equipment, both for power and lighting, so that navigation can proceed by night as well as by day. For the years 1903-7 the canals were declared *free of tolls*; but it is estimated officially that if tolls on the ordinary scale had been collected the revenue for 1907 would have exceeded 91,000*l*. In these five years the water-borne traffic of the Dominion increased from 9,204,000 tons in 1903 to 20,544,000 tons in 1907; in the same period the increase in Canadian railway traffic was from 47,373,000 tons to 63,866,000 tons. The official reporter justly remarks that 'these results are exceedingly encouraging.'

It was recognised long ago that the utilisation of the waterways of Canada from the Great Lakes to the sea would yield considerable advantages by facilitating cheap transport of agricultural products of the fertile regions from the great North-West, but the Canadian portions of that territory were then regarded as 'a great lone land.' Subsequent developments of the corn-growing regions of Canada have emphasised the value of the water route and its great potentialities. In his 'History of Merchant Shipping' (published 1876) Lindsay dwelt upon this point, and foresaw that if the waterways of Canada were made continuously navigable a struggle for supremacy in over-sea trade must arise between New York and the Canadian ports of Montreal and Quebec. This struggle is now in full force, so far as the grain trade is concerned, and it is likely to grow keener. The quantity of grain passed down the whole length of the St. Lawrence navigation to Montreal increased from about 450,000 tons in 1906 to 685,000 tons in 1907, while the quantity carried to Montreal by the Canadian Pacific Railway was about 387,000 tons for 1906 and 384,000 tons for 1907. On the other hand, the quantity carried by canals in the United States to New York fell from 294,500 tons in 1906 to 230,800 tons in 1907.

An important addition to the Canadian canal system has been proposed, and its execution will probably be undertaken when great works now in progress have been completed. This route extends from Georgian Bay on Lake Huron to the St. Lawrence, and would utilise Lake Nipissing as well as the French and Ottawa rivers. The distance to be traversed would be 450 miles less than that of the present all-water route. On the basis of careful surveys it has been estimated that a canal having 20 feet depth of water could be constructed at a cost of twelve millions sterling, upon which capital a reasonable dividend could be paid, even if the charges made for transport were one-third less than the lowest rates of freight possible on United States routes to New York. It would, of course, be most advantageous to have the available depth of water increased from 14 to 20 feet, thus making possible the employment of larger and deeper draught vessels between the Lakes and Montreal. Considerable economies in the ratio of working expenses to freight earnings would be effected, break of bulk in transit to the sea would be avoided, and the cost of transport greatly reduced.

The magnitude of the grain trade and its growth may be illustrated by the following figures for recent years:—In 1897 the grain cargoes passed down the Welland Canal to the ports of Kingston and Prescott numbered 377 and represented 515,000 tons; for 1907 the corresponding figures were 518 cargoes, weighing 841,000 tons. As to the elevators and mechanical appliances for handling economically these huge quantities of grain, nothing can be said here, although they involve the solution of many difficult engineering problems and have been greatly simplified and improved as experience has been gained.

The bulk of the canal traffic, of course, moves eastwards and outwards from

the interior provinces. For example, of the total quantity of freight (1,604,321 tons) passed through the whole length of the Welland Canal in 1907 about 75 per cent. moved eastwards, and more than 62 per cent. of the 2,100,000 tons which passed through the St. Lawrence canals moved in the same direction.

Shipping on the Great Lakes.

Canadian shipping and shipbuilding on the Lakes have made considerable progress in recent years, although they do not rival those of the United States. According to authoritative statements there were not twenty Canadian steamers engaged in the transport of grain fifteen years ago; only three of these were steel-built, and the largest carried only 90,000 bushels. The total carrying capacity of Canadian grain-carriers at the present time has been estimated at ten million bushels, and the capital invested in the fleet is said to be about three millions sterling. Between the harvest and the close of navigation in winter it is estimated that no less than sixty million bushels of grain can be moved from port to port in Canadian steamers.

Many special engineering features have been introduced into the structures and equipment of these Lake grain-carriers. They are really huge steel barges of full form, of uniform cross-section for a considerable portion of their length; and they possess enormous cargo capacity, moderate engine power and speed, with structures of a simple nature which can be largely standardised and made to resemble bridge-construction rather than ordinary shipbuilding. They can be built in a short time, the largest vessels occupying about four months in construction. In this way the cost of construction is cheapened, but the rates for labour and materials prevailing in the Lake shipyards are so high relatively to British costs that at present these grain-carriers are said to cost about 40 per cent. more (per ton dead weight carried) than the cost of ordinary 'tramp' steamers built in Great Britain. Their holds and hatchways are arranged so as to facilitate the rapid shipment and discharge of cargoes. At their ports of call special mechanical appliances are provided for dealing with cargoes, most of which consist of grain, ore, or coal.

In the design and construction of these cargo-handling appliances the mechanical engineer has displayed great ingenuity, and the results obtained in rate of shipment and discharge of cargoes of grain, ore, and coal are remarkable. Cases are on record where vessels carrying 7,000 tons dead weight have been loaded in four hours and discharged in ten hours; more than 5,000 tons of ore have been discharged in about four hours. The draught of water of the steamers must be kept within moderate limits and the breadths of the locks are moderate, so that increase in carrying power must be chiefly obtained by increase in length; consequently, as individual cargoes are increased, a greater number of lifting appliances can be brought to bear simultaneously, and the rate of loading or discharge can be maintained or accelerated.

The season of navigation extends over only seven or eight months in the year; consequently, 'quick despatch' is essential to success. A large vessel of this class has the following approximate dimensions:—Length about 600 feet; breadth, 58 to 60 feet; depth, 32 feet; draught of water, 19 to $19\frac{1}{2}$ feet when carrying 10,000 to 11,000 tons of cargo; corresponding displacement, 16,000 tons. The engines of such a ship develop about 2,000 horse-power, and drive her at eleven to twelve statute miles per hour in fair weather. The large size and moderate speed result in very economical conditions of working, and the freight rates are exceedingly low. From official returns it appears that for these dead-weight cargoes the freight across the Lakes is from ·04 to ·05 of a penny per ton mile, the corresponding railway rate being about ten times that amount. The multiplication of this type of vessel on the great Lakes is a proof that it satisfactorily fulfils the conditions of service. Similar vessels would not be well adapted for ocean work,

which demands greater structural strength, different proportions, and a more liberal equipment; but shipbuilders generally may benefit from a study of the Lake steamers.

The greater portion of the traffic on the Lakes passes through the 'Soo' canals. The voyages are comparatively short, the average length of the trip being about 840 miles. Consequently, individual vessels make several passages during the season when navigation is open, and the total number of passages as well as the total aggregate tonnage of the ships reaches very high figures. In the season of 1907, for example, when the canals were open less than 240 days, 20,440 vessels (counting as a vessel each passage), with an aggregate registered tonnage exceeding 44 million tons, passed through the United States and Canadian canals at the Soo. The aggregate freight tonnage carried exceeded 58 million tons; the weight of coal approached 11½ million tons; the iron ore carried weighed 39,600,000 tons; and the grain transported amounted to 136 million bushels. The conditions of the Suez Canal are, of course, entirely different, as vessels passing through are engaged on long voyages, and individual ships make few passages in the year. On the other hand, Suez Canal traffic proceeds uninterruptedly throughout the year, while the Soo canals are closed during the winter months. Subject to these differences in working conditions, it may be of interest to state that in 1907 4,267 vessels of 14,728,000 tons passed through the Suez Canal and paid transit dues which amounted to 4,460,000*l.*; whereas the passage of the 'Soo' canals was free.

The St. Lawrence Ship Channel.

Closely allied with the waterway from Montreal to Lake Superior is the improvement of the channel of the St. Lawrence from Montreal to Quebec and beyond towards the sea. From the Straits of Belleisle to Montreal the distance is 986 miles; from Quebec to Montreal it is 160 miles. Formerly the minimum depth of water between Quebec and Montreal prevented the passage of vessels drawing more than 10 to 12 feet during the greater part of the season of navigation. In 1826 the question of deepening the river channel was raised; in 1844 the work was begun, but was abandoned three years later; in 1851 it was resumed, and has since been continued. In 1869 the minimum depth of the channel at low water was increased to 20 feet, in 1882 it was 25 feet; in 1888 27½ feet for 108 miles from Montreal to a point within tidal influence. A channel having a minimum width of 450 feet, and 550 to 750 feet wide at the bends, with a minimum depth of 30 feet was completed in 1906 from Montreal to tide water at Batiscan. Certain work remains to be done between this point and Quebec in order to complete the project adopted in 1889 and amended in 1906, but it is anticipated this will be finished in about four years. Below Quebec the channel is 1,000 feet wide. When once dredged it is stated that the channel remains permanent. Accidents in the channel are few. The Superintending Engineer in his report of July 1908 indicates the magnitude of the work done by comparisons with the Suez and Panama Canals, the figures standing as follow:—

—	Length. Miles.	Minimum depth. Feet.	Minimum breadth. Feet.	Estimated excavation. Cubic yards.
Suez Canal	100	29½	100 (bottom)	—
Panama Canal	49	41	200 (minimum) 500 (maximum)	80,000,000
St. Lawrence Channel	220[1]	30	450 (minimum) 1,000 (maximum)	70,000,000

[1] Length of channel requiring improvement demands dredging and excavation over a length of about 70 miles.

In 1844 the largest vessels navigating the St. Lawrence to Montreal were of 500 tons; now the *Virginian* and *Victorian* of the Allan Line (12,000 tons), and the *Laurentic* and *Megantic* of the White Star Line (15,000 tons), proceed to that port, and have made the passage from Quebec in less than ten hours. Ordinarily this passage occupies from eleven to twelve hours, the return passage being made in nine to ten hours.

In the execution of these great works a specially designed dredging plant, including several types, has been employed, and works about seven months in the year; and the rock dredging and blasting in the section below Quebec has involved great difficulty. The total amount of rock to be removed amounted to 1,700,000 cubic yards, extending over nearly three miles, and the whole bottom was covered with huge boulders, some of which were 30 to 40 tons in weight. These great masses had to be lifted before blasting and dredging was done. During the fiscal year 1907-8 the expenditure on dredging plant and dredging was nearly 132,000*l.*, and 4,832,000 cubic yards of material were removed. At the close of that year 56 millions of cubic yards out of the estimated total of 70 millions had been dredged; the length completed to 30 feet minimum depth was 59 miles out of 70 miles. These facts indicate the advanced condition of the undertaking and the prospect of its completion at an early date.

In order to secure the safe and continuous navigation of this channel by night as well as by day, under all conditions of weather, during the season when the river is open, every precaution and aid which engineering skill and invention can provide has been laid under contribution. A marine signal service, with telephonic equipment has been provided; submarine bells have been established for use in foggy weather; a complete system of buoys and lighting has been installed; the channel is periodically examined and swept to ensure that there are no obstructions; the question of prolongation of the season for navigation by the use of ice-breakers is being studied. The harbour of Montreal has been greatly improved in accommodation and equipment; and the aggregate tonnage as well as the average size of sea-going vessels using the port have been much increased. In 1898, 868 such vessels aggregating 1,584,000 tons arrived at Montreal; in 1907, 742 vessels aggregating 1,926,000 tons arrived. Of the latter, 522 vessels aggregating 1,525,000 tons were British. At the St. Charles Docks and Wharves, Quebec, in the season of 1907, 235 vessels of 1,009,000 tons were entered inwards, and 67 vessels of 249,000 tons outwards, the first outward steamer leaving on April 7, and the first ocean steamer arriving on April 26. The last arrival from the sea was on December 9, and the ice formed in the tidal basin on December 12.

Still further improvements of the St. Lawrence navigation are now proposed, and the work was commenced in 1907. It is intended to increase the depth of the channel to a minimum of 35 feet from the sea to Montreal, and the Superintending Engineer reported in 1908 that with certain moderate additions to the dredging and steam plant this work could be completed in six seasons. The widths and curves of the existing channel will not require any important changes, as they were designed from the first for the largest classes of steamships. When this increased depth has been obtained Montreal as a port will have an approach channel comparing favourably with that of other ports available for Transatlantic traffic. At Southampton the existing depth at low water in the approach channel is about 32 feet, and it is proposed to obtain 34 feet. At Liverpool the minimum depth at low water over the bar and in the approach channel in the Mersey is about 28 feet. The Ambrose Channel leading to New York is to have 40 feet depth at low water when the works are completed. Ample depth of water is of the first importance in the economical working of the largest and swiftest ships, and the Canadian Government has been well-advised in deciding to carry out the great scheme above described.

Water-power.

Canada has unrivalled resources in water-power, and its extent and possible utilisation have been made the subject of investigation by engineers for many years past. One of the most important memoirs on the subject was presented to the Royal Society of Canada, in his Presidential Address of 1899, by Mr. Keefer, C.M.G. In recent times many other engineers have studied the subject and carried out important works. Exact knowledge of the total power represented by the water-falls and rapids of the Dominion is not available, nor can any close estimate be made of the power which may be employed hereafter in factories, mills, or industrial processes, because profitable employment obviously depends upon commercial considerations, which must be governed largely by the localities in which water-power may be found, and the cost of works and of transmission of energy to places where it can be utilised. It has been estimated that on the line from Lake Superior through the chain of lakes and rivers leading to Niagara and thence through the St. Lawrence to the sea eleven millions horse-power may be developed.[1] Mr. Langelier has estimated that in the Province of Quebec the water-power aggregates more than eighteen millions horse-power; other provinces all possess large resources of the same kind as yet untouched. The most striking example of the utilisation of water-power is that on the Niagara River, which I had the good fortune to visit in 1904 during my Presidency of the Institution of Civil Engineers; the works on the Canadian side were then in full progress, and at a stage which enabled one to realise completely their great difficulty and immense scale. The three companies whose works are near the Falls on the Canadian side have provided for a total ultimate development of over 400,000 horse-power, and a fourth establishment lower down the river, intended chiefly for the use of Hamilton, is to develop 40,000 horse-power. In the construction of the works, in the electric generating plant, the arrangements for transmitting power over long distances, and other features of importance remarkable engineering skill and daring have been displayed. American capital and enterprise have had much to do with these undertakings, as they have with many other important Canadian enterprises; but it may be hoped that British capital will keep its lead and be freely employed in the development and utilisation of all the resources of the Dominion, including that magnificent asset its water-power. The applications of water-power are already very numerous, including not merely the creation of electrical energy and its use for lighting and power in towns and factories situated at considerable distances from the Falls, but for manufactures and industrial processes carried on near the Falls. Amongst these manufactures, that of aluminium and carbide of calcium may be mentioned, while paper- and pulp-mills and saw-mills constitute important industries. Great advances have been made in the transmission of electrical power over long distances, and very high pressures are being used. Electric traction on railways and tramways also derives its power from the same sources, and is being rapidly developed. In 1901 there were 553 miles of electric railways, and in 1907 815 miles.

Over-sea Trade and Transport.

It was remarked at the outset that a great truth is embodied in the old toast of 'Ships, Colonies, and Commerce,' and the efficient and economical transport of passengers, produce, and manufactured goods between the Dominions beyond the Seas and the Mother Country is essential both for the development of Colonial resources and for the continued prosperity of the United Kingdom. The British mercantile marine commands the larger

[1] The *Times Financial Supplement*, April 2, 1906, contains a valuable article on this subject, from which many of the above figures are taken.

portion of the carrying trade of the world; its earnings constitute a valuable item in the national income; it forms one of the strongest bonds of union between the various parts of the Empire. This general statement may be illustrated by reference to the over-sea trade of Canada and to the shipping engaged therein.

The total value of the Imports and Exports of the Dominion in 1898 was close upon 61 millions sterling; in 1908 it exceeded 130 millions sterling, having more than doubled within ten years. During the year ending March 31, 1908, the vessels which were entered at Canadian ports (*inwards from the sea*) carrying cargoes were classified as follows in the official returns:—

Ships.	Tons register.	Freight carried.		Crews.
		Tons weight.	Tons measurement.	
British . 2,603	4,539,256	1,306,822	254,373	165,078
Canadian. 2,803	718,490	202,939	1,449,054	44,594
Foreign . 2,878	1,758,549	887,154	36,618	86,293
Totals . 8,284	7,016,295	2,396,915	1,740,045	295,965

The corresponding figures for ships entered outwards for sea carrying cargoes were:—

Ships.	Tons register.	Freight carried.		Crews.
		Tons weight.	Tons measurement.	
British . 2,533	4,258,960	2,706,334	714,085	136,614
Canadian . 3,557	1,041,053	616,248	291,480	45,658
Foreign . 4,132	2,211,605	1,454,787	538,499	88,093
Totals . 10,222	7,511,618	4,777,369	1,544,064	270,365

Taking the combined over-sea traffic inwards and outwards, it employed 18,506 ships of 14,528,000 tons, whose cargoes aggregated 7,174,000 tons dead-weight and 3,284,000 measurement tons, the crews exceeding 576,000 officers and men.

Of the 2,603 British ships entered inwards there came from Great Britain 852 ships of 3,392,000 tons, carrying as cargoes over 860,000 tons dead-weight and 153,600 tons measurement; while there came from British Colonies 399 ships of nearly 381,000 tons, carrying cargoes of 236,000 tons dead-weight and 44,000 tons measurement. Of the 2,533 British ships entered outwards there proceeded to Great Britain 732 ships of 2,529,000 tons, carrying cargoes of 1,635,000 tons dead-weight and 509,000 tons measurement; while there sailed for British Colonies 648 ships of nearly 400,000 tons, carrying cargoes of 259,000 tons dead-weight and 76,500 tons measurement.

It will be seen, therefore, that the British ships entered inwards carried more than 54 per cent. of the total dead-weight cargoes and $14\frac{1}{2}$ per cent. of the measurement goods, while foreign ships carried about 37 per cent. of the dead-weight and rather more than 2 per cent. of the measurement goods. British ships entered outwards carried more than 56 per cent. of the total dead-weight, and more than 46 per cent. of the measurement; whereas foreign ships carried only about 30 per cent. of the dead-weight, and not quite 35 per cent. of the measurement.

The trade from and to ports in the British Empire amounted to 45 per cent. of the grand total dead-weight freight; and ships carrying the British flag—excluding Canadian vessels—carried about 56 per cent. of the grand total dead-weight and nearly 30 per cent. of the measurement goods. Including Canadian vessels, the British Empire can claim possession of 67½ per cent. of the total dead-weight trade and 82½ per cent. of the measurement goods. The average tonnage per ship for the British was about 1,700 tons; for the Canadian vessels less than 300 tons; for the foreign ships a little more than 900 tons.

It may be interesting to add a few figures showing the magnitude of the *coasting trade* of the Dominion. In 1908 there arrived and departed 104,527 steamers aggregating nearly 42,857,000 tons, and 50,710 sailing ships aggregating 7,673,000 tons. The sailing ships included nearly 50,200 small schooners, sloops, barges, canal boats, &c., averaging about 150 tons each. The grand totals for the coasting trade were 155,237 ships of 50,530,000 tons, and of these 151,873 ships of 47,356,000 tons were classed as British in the official returns. It will be obvious that great importance must attach to every detail of the business involved in carrying on a shipping trade of the magnitude indicated by the foregoing figures, and still more is this the case in regard to the immensely greater transactions of British shipping considered as a whole. No pains must be spared in promoting economy or improving procedure, and even minute savings on particular items must be secured, since their aggregate effect may be of vast amount.

Since the introduction of iron for the structures of ships and of steam as the propelling power marvellous economies have been effected in the cost of over-sea transport. The chief causes contributing to this result have been (1) improvements in steam machinery, leading to great reductions in coal consumption, (2) considerable enlargement in the dimensions of ships, and (3) the supersession of iron by steel for structures and machinery. It is unnecessary, and would be impossible on this occasion, to deal in any detail with these matters, which have been illustrated repeatedly by many writers, including the speaker. On the other hand, it would be improper to leave altogether without illustration the remarkably low cost of sea transport under existing conditions, since it has great influence on the commerce of the British Empire and of the world.

Rates of freight, of course, vary greatly as the conditions of trade and the stress of competition change. At the present time these conditions remain unfavourable, although it may be hoped that there are signs of improvement, after long and severe depression. It will be preferable, therefore, to give facts for more normal circumstances, such as prevailed five or six years ago. Coal was then carried from the Tyne to London (315 miles) for 3*s.* 3*d.* a ton; to Genoa (2,388 miles) for 5*s.* a ton; to Bombay (6,358 miles) for 8*s.* 6*d.* a ton, including Suez Canal dues. The corresponding rates of freight were .111, .025, and .016 of a penny per ton-mile.

Grain was brought across the Atlantic for 9*d.* per quarter in large cargo steamers, whereas in former times, when it was carried in small vessels, the charge was 9*s.* 6*d.* Goods were carried 6,400 miles eastward *viâ* the Suez Canal in tramp steamers at an inclusive charge of 25*s.* to 30*s.* a ton, the freight rate averaging about .05 of a penny per ton-mile. It was estimated at that time that the average railway rate per ton-mile in Great Britain for cost of transport and delivery of goods was about thirty times as great; but the moderate distances travelled, local and national taxation, high terminal charges, and the immense outlay involved in the construction, equipment, and maintenance of railways account for much of the great difference in cost of transport. The ocean furnishes a free highway for the commerce of the world.

Economy of fuel-consumption has played a great part in the reduction

of working expenses in steamships. Fifty years ago from 4 to 5 lb. of coal per indicated horse-power represented good practice in marine engineering for screw steamships. At present, with quadruple expansion engines, high-steam pressures, and more efficient reciprocating engines, from $1\frac{1}{4}$ to $1\frac{1}{2}$ lb. is common practice, and better results are claimed in some cases. A cargo steamer of the tramp type, carrying 6,500 tons dead-weight, can cover about 265 knots in twenty-four hours in fair weather for a coal consumption of 27 tons per day, representing an expenditure on fuel of 20*l.* to 25*l.* A larger vessel carrying about 12,000 tons dead-weight, driven by engines of similar type, would consume about 45 tons in covering the same distance at the same speed. This increased economy in fuel per ton-mile is the result of an increase in dimensions from 365 feet length, 47 feet breadth, and $24\frac{1}{2}$ feet draught of water to a length of 470 feet, a breadth of 56 feet, and a draught of $27\frac{1}{2}$ feet. The first cost of cargo steamers is small in relation to their carrying capacity and possible earnings ; varying, of course, with the current demand for new steamships. In the present depressed condition of shipping, about 5*l.* 10*s.* per ton dead-weight is named as a current rate ; in busy times the price may be 40 to 45 per cent. higher ; even then it is small in proportion to earning power. Working expenses are kept down also by the use of efficient appliances for rapidly shipping or discharging cargoes, and so shortening the stay of ships in port. As an example a case may be mentioned when a ship of 12,000 tons dead-weight and 800,000 cubic feet measurement capacity had her full cargo discharged at an average rate of 300 tons an hour, a fresh cargo put on board at the rate of 250 tons an hour, and 1,600 tons of coal shipped between 7 A.M. on Monday and noon on the following Friday—that is, in 101 hours. In another case a cargo weighing 11,000 tons was discharged in 66 hours. 'Quick dispatch' in dealing with cargo is now universally recognised as essential, and it has been asserted that a saving of one day in the time occupied in discharging or loading a tramp steamer when she finds full employment may involve an economy equal to one per cent. on her first cost.

The 'intermediate' type of steamer—in which large carrying capacity is combined with provision for a considerable number of passengers and moderate speed—is of comparatively recent date, but it has been developed rapidly and is subject to the universal laws to which all classes of shipping conform. Increase of size is adopted in order to favour economy in working and greater earning power, while increase in speed is made in some cases. Vessels like the *Adriatic* or *Baltic* of the White Star Line, the *Carmania* and *Caronia* of the Cunard Line, and the *George Washington* of the Hamburg-American Line illustrate this statement ; while its latest and greatest examples are found in the two steamers now building for the White Star Line by Messrs. Harland and Wolff, which are said to be of 45,000 tons, to be intended to steam twenty to twenty-one knots, to provide accommodation for a great number of passengers, and to have large capacity for cargoes. In mail and passenger steamers of the highest speed increase in dimensions is devoted chiefly to provision for more powerful propelling apparatus and for a correspondingly large quantity of fuel, and the cargo-carrying capacity is relatively small ; but the law of increase in size and cost is obeyed, and will be followed up to the limit which may be fixed by the vast outlay necessary in order to provide suitable harbours and dock accommodation with an adequate depth of water, or by commercial considerations and the possibility of securing a suitable return on the large capital expenditure. Growth in dimensions of ships will not be determined by the naval architect and marine engineer finding it impossible to go further, for there are even now in view possibilities of further progress if the shipowner so desires. Invention and improvement have not reached their ultimate limits.

The wonderful progress made during the last seventy years is well illustrated by the history of shipping trading between Canada and Great Britain.

and it may be of interest to recall a few of the principal facts. For a long period trade and communications were carried on by wood-built sailing ships, many of the finest being Canadian built; but at a very early period Canadians had under consideration the use of steamships. One of the first steamers to cross the Atlantic was the *Royal William* paddle-steamer, built near Quebec in 1831. She was 160 feet long, 44 feet broad, of 363 tons burden, sailed from Quebec on August 5, 1833, and reached Gravesend on September 16, a passage of more than forty days, in the course of which sail-power was largely used. Cabot, in 1497, crossed in the good ship *Matthew*, of 200 tons burden, which was probably from 90 to 100 feet in length; so that three centuries of progress had not made very great changes in size of the ships employed. Wood was still the material of construction, and sails were still used as a motive power, although the steam-engine was installed. In 1839 it was a Canadian, Samuel Cunard, who secured—in association with two British shipowners, Burns and McIver—the contract for a monthly Transatlantic service from Liverpool to Halifax and Boston. The four steamers built were wood-hulled, driven by paddle-wheels, had good sail-power, and were of the following dimensions: 207 feet long, 34½ feet broad, 1,150 tons burden, and about 8 knots speed. A rapid passage to Boston then occupied about fourteen days.

Another Canadian enterprise, the Allan Line, started about fifty-six years ago. The first steamer built for the company was appropriately named the *Canadian*. At the time of her construction she ranked among the most important mercantile steamers in existence, and was quite up to date. Her dimensions were: Length, 278 feet; breadth, 34 feet; burden, 1,873 tons. She had inverted direct-acting engines, driving a screw propeller, and a full sail equipment.

The Transatlantic service to New York, as was natural, rapidly surpassed that to Canadian ports, but the latter has been continuously improved, and its development has been marked by many notable events. For example, the Allan Line was amongst the first to use steel instead of iron for hulls, and in their two largest steamers now on service, dating from 1903, they were the first to adopt steam turbines for ocean-going ships, although their lead of the Cunard Company was not long. The *Virginian* and *Victorian* are 520 feet long, 60 feet broad, of 10,750 tons, and their maximum speed is 18 knots. The Canadian Pacific Railway authorities added shipowning to their great land enterprises at an early period in their career by building for the Pacific service in 1891 three important steamers, each 456 feet long, 51 feet broad, of 5,950 tons, and 17 knots speed. These vessels continue on service, and have done splendid work as a link in the 'all red' route. Since this step was taken the Canadian Pacific Railway has become possessed of a large fleet of Atlantic steamships, and quite recently has placed on the service from Liverpool to Quebec passenger steamships nearly 550 feet in length, 66 feet in breadth, of 14,200 tons, with a maximum speed of 20 knots.

The latest addition to the Canadian service has been made by the White Star Line in the form of two steamers, the *Laurentic* and *Megantic*, of 15,000 tons, 550 feet long, about 67 feet broad, and 17 knots speed. In the *Laurentic* an interesting experiment has been made—Messrs. Harland & Wolff having introduced a combination of reciprocating engines and a low-pressure turbine. This system was patented as long ago as 1894 by Mr. Charles Parsons, to whom the invention of the modern steam turbine and its application to marine propulsion are due. Mr. Parsons foresaw that while the turbine system would prove superior to reciprocating engines in ships of high speed and with a high rate of revolution, there would be a possibility of getting better results by combining reciprocating engines with low-pressure turbines in ships of comparatively slow speed, where a low rate of revolution for the screw-propellers was necessary to efficient propulsion.

His main object, as set forth fifteen years ago, was 'to increase the power obtainable by the expansion of the steam beyond the limits possible with reciprocating engines,' and subsequent investigations led Mr. Parsons to the conclusion that it would be possible to secure an economy of 15 to 20 per cent. by using the combination system as compared with that obtainable with efficient types of reciprocating engines. Many alternative arrangements have been designed for combining reciprocating engines with low-pressure turbines; that now under trial associates twin-screw reciprocating engines, in which the expansion of the steam is carried down to a pressure of 9 to 10 lbs. per square inch when working at maximum power, and then completed to the condenser pressure in a turbine. Triple screws are employed, the central screw—driven by the turbine—running at a higher rate of revolution than the side screws, which are driven by the reciprocating engines. The *Laurentic* has been but a short time on service, and few particulars are available of her performances as compared with those of her sister ship, fitted with reciprocating engines. It has, however, been reported that the results have proved so satisfactory that the combination system will probably be adopted in the two large White Star steamers of 15,000 tons now building at Belfast. This favourable view is fully confirmed by the performances of the *Otaki*, built by Messrs. Denny, of Dumbarton, for the New Zealand Shipping Company, and completed last year. That firm, as is well known, have taken a leading part in the application of the Parsons type of steam turbine to the propulsion of mercantile and passenger steamers, and they possess exceptional experience as well as special facilities for the analysis of the results of trials of steamships, having been the first private firm to establish an experimental tank for testing models of ships and propellers on the model of that designed by Mr. W. Froude and adopted by the Admiralty. Messrs. Denny have generously placed at the disposal of their fellow-shipbuilders the principal results obtained on the official trials and earliest voyages of the *Otaki*, and have compared them with similar results obtained in sister ships fitted with reciprocating engines.[1] The *Otaki* is the first completed ship fitted with the combination system and subjected to trial on service, and as the successful application of that system to cargo steamers and steamers of the intermediate type would result in a considerable economy in the cost of oversea transport, it may be of interest to give some details of her recorded performance. She is 465 feet long, about 60 feet broad, and of 7,420 tons (gross). Her dead-weight capability is about 9,900 tons on a draught of 27 feet 6 inches, and the corresponding displacement (total weight) is 16,500 tons. The vessel was designed for a continuous sea-speed of 12 knots when fully laden, and the contract provided for a trial speed of 14 knots with 5,000 tons of dead-weight on board. The trials were accordingly made at a displacement of about 11,700 tons. Her installation of boilers is identical with that of her sister ship, the reciprocating-engined twin-screw steamer *Orari*, which is 4 feet 6 inches shorter than the *Otaki*, but generally of the same form. On the measured mile the *Otaki* obtained a speed of 15 knots, while the *Orari* reached 14·6 knots. In order to drive the *Orari* at 15 knots about 12 per cent. more horse-power would have been required, and this is a practical measure of the superiority of the combination system over the reciprocating twin-screw arrangement in the *Orari*. The total water consumption per hour of the *Otaki* at 15 knots was 6 per cent. less than that of the *Orari* at 14·6 knots. If the *Otaki* also ran at 14·6 knots, the water consumption would have been 17 per cent. less than that of the *Orari* at the same speed. On the voyage from Liverpool to New Zealand the *Otaki* averaged about 11 knots, which would have required on the measured mile only about 40 per

[1] See a paper by Engineer Commander Wisnom, R.N., in the *Proceedings of the Institution of Engineers and Shipbuilders in Scotland for* 1909.

cent. of the power developed when running 14·6 knots. With the ship laden more deeply, the average development of power on the voyage was about one-half the maximum developed on the measured mile, and this was disadvantageous to economy in the combination. Even in these unfavourable conditions the *Otaki* realised an economy in coal consumption of 8 per cent. on the voyage from Liverpool to New Zealand and back as compared with her reciprocating-engined sister ship ; this represents a saving of about 500 tons of coal. Ordinarily the ship would leave England with sufficient coal on board for the outward passage, so that 250 tons less coal need be carried and a corresponding addition could be made to cargo and freight-earning. Probably as experience is gained the actual economy will prove greater than that realised on the maiden voyage ; but even as matters stand there is a substantial gain, and a prospect of the extended application of the steam turbine to vessels of moderate and low speed. In view of results already obtained, the New Zealand Shipping Company have decided to apply the combination system to another vessel just ordered from Messrs. Denny.

In designing turbine machinery for vessels of moderate or low speed there must necessarily be conflicting claims. For maximum efficiency in steam turbines a high rate of revolution is necessary ; whereas at moderate or low speeds it is antagonistic to propeller efficiency to run at this high rate of revolution. Engineers are at present much occupied with the study of arrangements by means of which these conflicting claims may be harmonised and greater total efficiency of propulsion obtained. Having regard to the enormous capital invested in cargo steamers of moderate speed, and the importance attaching to their economic working as influencing the cost of oversea transport, it will be obvious that it is most desirable to find an arrangement in which the high speed of the rotor may be reduced by means of some form of gearing or its equivalent, so as to enable the screw shaft and its propeller to be run at a speed which will secure maximum propeller efficiency. Many proposals have been made, including mechanical gearing and hydraulic or electric apparatus for transforming the rate of motion. Some of these are actually undergoing experimental trials, and are said to have given very promising results. One of the most important trials is that undertaken by the Parsons Marine Steam Turbine Company, which has purchased a typical tramp steamer, and is carrying out on her a series of trials in order first to ascertain accurately what are the actual conditions of steam and coal consumption with the present reciprocating engines, and then to ascertain the corresponding facts when those engines have been removed and a steam turbine with its associated gearing has been fitted. It is interesting to note in passing that in the earliest days of screw propulsion with slow-running engines it was found necessary to adopt gearing in order to increase the rate of revolution of the propellers, whereas at present interest is centred in the converse operation. Furthermore, if any system of gearing-down proves successful it may be anticipated that its application will be extended to swift turbine-driven steamships, since it would enable good propulsive efficiency to be secured in association with rapidly running turbines of smaller size and less weight than have been employed hitherto.

The Marine Steam Turbine.

The rapid development of the marine steam turbine during the last seven years constitutes one of the romances of engineering, and the magnitude of the work done and the revolution initiated by Mr. Charles Parsons will be more justly appreciated hereafter than they can be at present. In some quarters there is a tendency to deal critically with details and to disregard broader views of the situation as it stands to-day. In May 1909 there were 273 vessels built and under construction in which steam turbines of the

Parsons type are employed, the total horse-power being more than three and a half millions. In the Royal Navy every new warship, from the torpedo-boat up to the largest battleships and armoured cruisers, is fitted with turbine engines; and the performances of vessels which have been tested on service have been completely satisfactory, in many instances surpassing all records for powers developed and speeds attained. In the war-fleets of the world this example is being imitated, although in some cases it was at first criticised or condemned. In the mercantile marine as a whole, while the new system has not made equal advance, many notable examples can be found of what can be accomplished by its adoption. It is now admitted that steam turbines enable higher speeds to be attained in vessels of given dimensions; and in steamers built for cross-channel and special services, where high speed is essential and coal consumption relatively unimportant, turbines have already ousted reciprocating engines. For oversea service and long voyages an impression has existed that the coal consumption of turbine-engined ships would considerably exceed that of ships driven by triple or quadruple expansion reciprocating engines. Critics have dwelt on the reticence in regard to actual rates of coal consumption practised by owners of turbine steamships. Naturally there are other reasons for reticence than those which would arise if the coal consumption were excessive; but pioneers in the use of turbine machinery may reasonably claim the right of non-publication of results of trials in the making of which they have incurred large expenditure and taken considerable risks, if they think that silence is beneficial to their business interests. Even if it were true that in the earliest applications of the new system economic results had not been obtained equal to those realised in reciprocating engines which have been gradually improved during half a century, that circumstance should not be regarded as a bar to acceptance of a type of engine that admittedly possesses very great advantages in other ways, but should be regarded as an incentive to improvements that would secure greater economy of coal. The evidence available, however, does not confirm the adverse view, and those familiar with the facts do not admit its truth. One example may be cited as it affects the Canadian service. In June 1907 it was authoritatively stated that in the Allan liner *Virginian* the reports which had been circulated respecting the excessive coal consumption were unfounded, that the vessel was making passages at speeds of $17\frac{1}{2}$ to $17\frac{3}{4}$ knots, as against the 17 knots estimated, and the rate of coal consumption was really about 1·4 lbs. per indicated horse-power which would have been required to attain this speed if the vessel had been fitted with reciprocating engines. This result compares well with the consumption in ordinary passenger steamers running at high speeds in proportion to their dimensions, although in large cargo steamers and vessels of the intermediate type, working under much easier conditions and at very low speeds in proportion to dimensions, lower rates of consumption may be obtained. With these latter vessels the fair comparison is the combination system and not the pure turbine type which is adapted for high speeds.

The crowning triumph of the marine steam turbine up to the present time is to be found in the great Cunard steamships *Lusitania* and *Mauretania*. The passages made this year by the latter ship since she was refitted have been marvellously regular, and the 25 knots average across the Atlantic, which was the maximum contemplated in the agreement between the Government and the Cunard Company, has been continuously exceeded. As one intimately concerned with the design of the *Mauretania*, who has had large experience in ship design, has made a life-long study of the laws of steamship performance, and had the honour of serving on the committee which recommended the employment of turbines in these great ships, I venture to assert that equal results could not possibly have been obtained with reciprocating engines in vessels of the same form and dimen-

sions. Contrary opinions have been expressed, but they either have been based upon incorrect data or have omitted consideration of the fact that in vessels of such great engine-power it was necessary to have time to perfect the organisation of the staff in order to secure uniform conditions of stoking and steam production, and to bring the 'human element' into a condition which would ensure the highest degree of efficiency in working the propelling apparatus. This necessity for time and training has been illustrated again and again in the case of new types of Transatlantic steamers, including some which held the record for speed prior to the appearance of the Cunarders. In the *Lusitania* and *Mauretania* the engine-power is fully 60 per cent. greater than that of their swiftest predecessors, yet no similar allowance appears to have been thought necessary by some critics, who assumed that performances on the earlier voyages represented the maximum capabilities of the vessels. Subsequent events have shown this view to be fallacious and have justified the recommendation of the Turbine Committee and the action of the Cunard directors. Allegations made in regard to excessive coal consumption have also been disproved by experience; and in this respect the anticipations of the committee and of Mr. Parsons have been fully realised.

The marvellous regularity maintained by the *Mauretania* on a long sequence of consecutive Transatlantic passages—made under varying and in many cases very adverse conditions of wind, weather, and sea—illustrates once more, and on an unprecedented scale, the influence which large dimensions have upon the power of maintaining speed at sea. Starting from the eastward passage, beginning on February 3rd last, and taking twelve passages (westward and eastward) which followed, the average speed for the thirteen passages, approaching 40,000 sea miles in length, has been 25½ knots; the lowest average speed in the series has been 25·2 knots, the highest average speed 25·88 knots. Many of the passages in this series were made in winter weather against strong winds and high seas, which would have considerably reduced the speed of her predecessors, but had small influence on the *Mauretania*. In many instances delays have been caused by fogs.

On seven consecutive passages made since the beginning of last May the average speed of the *Mauretania* in covering about 20,000 sea-miles has been 25·68 knots, the minimum speed for the passage having been 25·62 knots and the maximum 25·88 knots. On her contract trials the *Mauretania* maintained an average speed of 26·04 knots for a distance somewhat exceeding 1,200 knots, the steaming time being rather less than forty-eight hours. On the passage when she averaged 25·88 knots, she ran 1,215 knots from noon on June 17th to noon on June 19th (about forty-six hours), at an average speed of 26·23 knots, and by noon on the 20th had covered 1,817 knots at an average speed of 26·18 knots for 69 hours. The ship has, therefore, surpassed on service her performance on the contract trial.

In view of the foregoing facts and of others of a similar nature, it is reasonable to assume that as experience is enlarged and information is accumulated in regard to forms of propellers likely to prove most efficient in association with quick-running turbines, sensibly improved performances will be obtained. At present, in comparisons made between the efficiency of reciprocating-engined ships and turbine-engined ships, the former have the great advantage attaching to long use and extended experiment; but this is not a permanent advantage, and it may be expected that good as the position is to which the marine steam turbine has attained in the brief period it has been in practical use, that position will be gradually improved. Whether or not other forms of propelling apparatus in their turn will surpass the steam turbine it would be unwise to predict. Internal combustion engines are regarded in some quarters as dangerous and probably successful rivals to steam turbines in the near future. Within certain

limits of size, internal combustion engines no doubt answer admirably; but as dimensions and individual power of the engines are increased, the difficulties to be overcome also rapidly increase, and the fact is fully recognised by those having the best knowledge of those types of prime movers. On the whole, therefore, it seems probable that the turbine will not soon be displaced, whatever may happen eventually.

An Imperial Navy.

Three centuries ago a great English seaman and coloniser wrote these words:—

> 'Whomsoever commands the sea commands the trade;
> Whomsoever commands the trade of the world commands the riches of the world, and consequently the world itself.'

In these words Sir Walter Raleigh clearly expressed the doctrine of 'sea-power,' which in recent times has been emphasised by Admiral Mahan of the United States Navy and other writers. Twenty years ago when the movement began which has been followed by an unprecedented series of ship-building programmes, great additions to the *personnel* of the Royal Navy and large expenditure on improvements of existing naval bases and the creation of others at important strategical points, the same truth was expressed in a report made by three distinguished Admirals, one of whom, Admiral of the Fleet Sir Frederick Richards, subsequently became First Naval Lord of the Admiralty, and did much to give effect to the policy he had joined in recommending. One passage in this report may be quoted: 'No other nation has any such interest in the maintenance of an undoubted superiority at sea as has England, whose seaboard is her frontier. England ranks amongst the great Powers of the world by virtue of the naval position she has acquired in the past, and which has never been seriously challenged since the close of the last great war. The defeat of her Navy means to her the loss of India and her Colonies, and of her place amongst the nations.'

The 'maintenance of an undoubted superiority at sea' in existing circumstances and in face of foreign competition is no easy task, and it is good to know that the Dominions beyond the Seas are ready to take a share of the heavy burden of Empire. In what way effect can best be given to this fundamental idea it is not easy to decide. It is necessarily a matter in which the views of all concerned must be considered, and a policy determined on which shall command hearty support from all portions of the Empire. It may be presumed that the arrangement of such a policy has been the chief object of this year's Defence Conference. The decision which may be reached and the action taken must exercise momentous influence upon the destiny of the Empire. Universal approval has been given to the arrangement for that Conference, and this is a happy augury of its ultimate success in framing a satisfactory scheme for the construction and maintenance of an Imperial Navy. Many valuable suggestions have been made by British and Colonial authorities as to the great lines on which such a scheme should be drawn, but this is not the place to enter upon a discussion of the subject. It may be permitted, however, as a sequence to the preceding remarks on oversea transport, to remark that the protection of trade routes between the Mother Country and the Dominions beyond the Seas constitutes an essential duty; in the performance of which duty, especially in portions of trade routes adjacent to the Colonies, naval forces maintained by the Colonies may render valuable service. Such a policy in no way infringes the fundamental condition that supremacy at sea ultimately depends upon battle-fleets; while it recognises the fact, which past struggles have demonstrated, that behind and beyond the work of battle-fleets lies the need for adequate protection of commerce and communications. Moreover, it leaves

Colonial Governments unfettered in making arrangements for the execution of that portion of the general scheme of defence which they may undertake; and there can be no inconvenience or loss from such independent action provided the scheme of Imperial defence has been considered as a whole, and an understanding reached in regard to the distribution of the work. At present the Mother Country alone possesses experience and means of manufacturing warships and armaments; so that gradual developments, requiring time and experience, will be necessary before the Colonies can become self-supporting in these respects should they desire to do so. On the side of *personnel* and its training also the Royal Navy must be the great school for all parts of the Empire. Finally, the full utilisation of Imperial defensive forces demands the existence of a complete understanding and the prearrangement of a common plan of campaign. In order to meet this essential condition there must be an Imperial staff.

The burden of naval defence has hitherto been borne almost entirely by the Mother Country. What the weight has been is hardly realised until the figures for expenditure are examined. As indications of what is involved in creating and maintaining a modern navy of the first class, it may be mentioned that in the ten financial years of the present century (including the current year 1909-10) the total expenditure on the Royal Navy amounts to 328 millions sterling. From 1885 to 1902, during the period I occupied the position of Director of Naval Construction and Assistant Controller of the Navy, the total outlay on the 245 ships for the designs of which I was responsible amounted to about 100 millions sterling. The stress of foreign competition and the growth in dimensions and cost of warships are leading to still greater expenditure on the Navy, and it is good to know that Canada, Australia, New Zealand, and South Africa are ready and willing to bear their share of the inevitable burden.

All branches of engineering have been and will be drawn upon freely in the execution of this great task. Mining and metallurgy assist by the production of materials of construction; mechanical and electrical engineers contribute machines and appliances required in shipyards and engine factories, as well as guns, gun-mountings, and mechanical apparatus of all kinds required in modern warships in order to supplement and economise manual power; marine engineers design and construct the propelling apparatus, and constantly endeavour to reduce the proportion of weight and space to power developed; naval architects design and build the ships; constructional engineers are occupied in the provision of docks, harbours, and bases adapted to the requirements of the fleet; and other branches of engineering play important if less prominent parts. The progress of invention and discovery is increasing, rapid changes occur unceasingly, the outlay is enormous, the task is never-ending, but its performance is essential to the continued well-being of the Empire, and it must and will be performed.

The following Paper was then read:—

Hydro-electric Power Plant for the City of Winnipeg.
By C. B. Smith, *M.Inst.C.E.*

FRIDAY, AUGUST 27.

The following Papers were read:—

1. *Improvements in the Navigation of the St. Lawrence.*[1]
By Lieut.-Colonel William P. Anderson, *M.Inst.C.E.*

---

[1] Published in *Engineering.*

2. *The St. Lawrence River, the Great Imperial Highway of Canadian Transportation.* *By* Major G. STEPHENS.

3. *The Georgian Bay Canal.* *By* Sir W. H. WHITE, *K.C.B., F.R.S.*

4. *The Engineering Works of the Panama Canal.*[1] *By* Colonel G. W. GOETHALS.

MONDAY, AUGUST 30.

The following Papers were read:—

1. *The National Transcontinental Railway.*[1] *By* DUNCAN MACPHERSON, *M.Inst.C.E.*

2. *Great Engineering Works on the Canadian Pacific Railway.*[1] *By* J. E. SCHWITZER.

3. *The High-pressure Service of the City of Winnipeg.* *By* Colonel H. N. RUTTAN.

4. *The Distribution of Dielectric Stress in Three-phase Cables.*[1] *By* Professor W. M. THORNTON, *D.Sc., and* O. J. WILLIAMS, *B.Sc.*

5. *Atmospheric Loss off Wires under Direct-current Pressures.*[2] *By* E. A. WATSON, *M.Sc.*

6. *On the Calculation of the Charging Currents in Three-core Cables and Overhead Transmission Lines supplied with Three-phase Currents.*[2] *By* E. W. MARCHANT, *D.Sc.*

TUESDAY, AUGUST 31.

The following Papers and Report were read:—

1. *The Development of the Grain Industry of Western Canada and its Future Possibilities.*[1] *By* G. HARCOURT.

2. *Grain Handling.*[1] *By* W. B. LANIGAN.

[1] Published in *Engineering.*

[2] Published in *The Electrician.*

3. *Note on the Application of Polarised Light to Determine the Condition of a Body under Stress. By* Professors S. P. THOMPSON, *F.R.S., and* E. G. COKER, *D.Sc.*

The application of polarised light to observe optically the strained condition of glass and other transparent materials when subjected to stresses has been known since the days of Brewster and Biot. When an ordinarily isotropic body, such as glass, is subjected to pressure or tension, it becomes in fact doubly-refractive, the axis of double-refraction being along the line of maximum stress; and the presence of such double-refraction is made evident by examining in the polariscope the light transmitted through the object.

Hitherto the usual disposition has been the following: An ordinary polariser, such as a large Nicol prism, or a black-glass reflector set at the polarising angle, is employed to produce plane-polarised light. An ordinary Nicol prism is used as analyser; and habitually their principal planes are crossed so as to produce the dark field. Then the piece of glass to be examined is placed between them, and means are provided, by pinching screws or compressors, to subject the glass to stresses in a plane normal to the axis of the beam of light through the Nicols. No effect is produced if the axis of double-refraction, that is, the axis of the strain, lies parallel to the plane of polarisation of either the polariser or the analyser. If the axis of double-refraction is at all oblique to such plane then more or less light is transmitted. As a result of this disposition the apparent amount of light seen through the polariscope varies according to the square of the sine of half the angle which the axis of stress makes with the plane of polarisation of the polariser; and the observed figure in the stressed specimen changes if it is rotated in its own plane in the instrument. This is further complicated, if the light be not monochromatic, by the chromatic differences in the double-refraction. Again, as is well known, and as a result of this maximum effect at 45°, if any object be taken in which the stresses are radial in direction—as is the case when a short cylinder or circular disc of glass has been subjected to sudden cooling, so that the peripheral portion contracts with great force upon the central portion—the object exhibits in the polariscope a black cross with its pairs of arms respectively parallel to the planes of polarisation of polariser and analyser, the light being a maximum in directions at 45° between the arms of the black cross. These arms remain fixed, even though the object be rotated in the apparatus. If other objects are used in which these naturally occur, equal strains will apparently produce unequal effects, because the different parts cannot be so placed that everywhere the axis of strain shall be all at the same angle with the principal axis of the apparatus, and there is an optical inequality, due to the very arrangement of the polariscope that does not correspond to any inequality in the specimen, or in the forces to which it is subjected.

Furthermore, in order to produce any very evident effects in glass, either the specimen must be very thick (as is the case of the pieces of unannealed glass generally employed in polariscopic demonstrations) or else the forces to which the glass is subject by the compressing screws must be so great as to come perilously near to breaking the object. Indeed, it is quite common, in the ordinary apparatus for showing these effects, for the little bars or squares of glass to be broken or crushed in showing the experiment.

Two things, therefore, need to be done in improving the means for studying and exhibiting optically the stresses in transparent solids: (1) to use a material more compressible than glass; (2) to devise optical means for getting rid of the black cross, and of making the optical effect independent of the particular angle at which the specimen, or any part of it, might be placed.

The first of these ends was obtained by the adoption of a particular kind of xylonite instead of glass. Xylonite is a preparation of nitro-cellulose in commercial use. It is not quite as transparent as glass, but it is transparent enough, even when of a thickness of ten millimetres, to be entirely useful. It is slightly tinted and slightly turbid. Sheets three or four millimetres thick are practically transparent. From such sheets or selected portions of sheets the objects to be experimented upon are cut out.

The second improvement, which is entirely successful in eliminating the

black cross, and in rendering the optical effect independent of the position of the specimen in the field, we have effected by the device of substituting circularly-polarising apparatus for both analyser and polariser. To this end we take two thin plates of mica (or of quartz cut parallel to the axis of crystallisation), selected so as to give as nearly as possible a retardation of one quarter-wave length for yellow light (D-line) between their ordinary and extraordinary rays. For many purposes ordinary so-called 'quarter-wave plates' will suffice: but the ordinary quarter-wave plates, as sold, differ considerably amongst themselves; and it is important that the pair chosen should be alike in optical property. One must be large, covering the whole field of view; the other may be quite small. The larger quarter-wave plate is placed between the polariser and the object, and is preferably attached to the polariser. It is set with its own axis at 45° to the plane of polarisation of the polariser. Thus set it transmutes the plane-polarised beam into a circular-polarised beam. The cheirality of this beam is right-handed or left-handed according to whether the axis is set at 45° to the left or at 45° to the right. The smaller quarter-wave is placed between the object and the analyser, and is preferably attached to the front of the analysing Nicol, to rotate with it, if the Nicol is turned. It also must be set with precision with its own axis at 45° to the plane of polarisation of the Nicol. If it receives a beam of circularly-polarised light it transmutes that beam into plane-polarised light, and this is either cut off or transmitted by the analyser, according to whether its own axis is at 45° to the left or to the right; or, in other words, according as to whether the cheirality of the analysing combination of quarter-wave and Nicol is opposed to, or concordant with, the cheirality of the polarising combination.

If the quarter-waves are so set as to give 'dark field,' then there will still be dark field even if the analysing combination be rotated through any angle. Or if they are so set as to give 'bright field,' then there will still be bright field for every position of the analysing combination. With this apparatus one cannot change, as in the ordinary polariscope, from 'dark field' to 'bright field' by turning the analyser through 90°. To do this requires that one or other of the quarter-waves must be rotated in its own plane through 90°, or be reversed face for face by turning through 180° around an axis parallel to the plane of polarisation of the Nicol with which it has been combined.

With the above disposition of circular polariser and circular analyser, *we get rid entirely of the black cross*; and, further, with the exception of certain slight changes of tint, *the optical appearance of any polarising object placed in the apparatus remains invariable at whatever angle that object may be placed in the field.*

---

4. *Second Report on Gaseous Explosions.*—See Reports, p. 247.

---

5. *The Work of the British Association Committee on Gaseous Explosions.*[1] *By* DUGALD CLERK, *F.R.S.*

WEDNESDAY, SEPTEMBER 1.

The following Papers were read:—

1. *International Electrical Standardisation.*[1] *By* ORMOND HIGMAN.

---

[1] Published in *Engineering.*

2. *The Behaviour of Ductile Material under Torsional Strain.*[1] *By* C. E. Larard, *Assoc.M.Inst.C.E.*

The researches reported in this paper were carried out on different diameters of wrought iron, mild steel, and nickel steel, varying from half an inch to three inches. Some of the results obtained may be summarised as follows:—

1. For ductile material there is no well-marked yield-point similar to that obtained for tension tests.

2. When the maximum torque is reached failure takes place by the specimen commencing first to shear round the periphery over a small annulus of material, this shear gradually extending inwards from annulus to annulus at a reducing torque until the final fracture of a more or less central core in tension, accompanied by a loud report. This failure in two stages is brought about by the irregularity in the form of the fracture during shearing, whereby a wedging action is set up over the large annulus surrounding the core, thus producing compression across the annulus and tension in the core. The diameter of the tension core is roughly proportional to the diameter of the specimen. For a homogeneous material the relationship between torque and local twist is given by a rectangular hyperbolic curve.

3. The torque-twist curve throughout the entire test, from the elastic limit to the breaking torque, follows a compound interest law, and an expression has been obtained by means of which the work to destroy the specimen can be calculated; and the result has been confirmed by integrating by means of a planimeter the autographic torque-twist diagram.

4. For a homogeneous material the work done is proportional to the volume, whatever the diameters and lengths of the specimens.

5. For a homogeneous material the torque at fracture is directly proportional to the cube of the diameter of the specimen, when the diameter varies.

6. (*a*) Principal transverse sections by planes at right-angles to the axis before twisting remain plane during twisting.

(*b*) The unitary structural parts of the material at different radii in a given section undergo during torsion the same angular displacement.

(*c*) Straight generating lines on the cylindrical surfaces before torsion are twisted up into helical lines, defining lines of helical shear.

(*d*) Any sector of a homogeneous cylinder is twisted up so as to form a sectorial screw.

(*e*) The shear stress at any radius and also along the helical lines may be calculated from the usual shaft formula.

(*f*) For a homogeneous material the angle of the helical lines of shear tends to have a constant value for any diameter of a specimen; consequently simple mathematical relationships between the variables of the experiments may be obtained.

7. A specimen under torsion undergoes changes in its dimensions, there being an axial elongation following the compound interest law and a small reduction in diameter. Further, it would appear that when work is done in producing plastic deformation with corresponding increase in elastic resilience the volume is slightly increased.

8. The elastic limit and the elastic resilience of material may be raised above the primary limit, which is purely an artificial one produced by manufacturing operations, (*a*) by overstraining, with full recovery of elasticity to a higher limit by heat treatment at low temperatures; (*b*) by indefinitely long rest after overstraining; (*c*) by continuous stressing of material at a fairly constant load above the primary elastic limit; (*d*) in

[1] Published in *Engineering*.

manufacturers' works by scientific straining with subsequent heat treatment; (*e*) considering the forms of iron and steel, by the addition of a small percentage of some other element. Any one of these methods increases the ratio of elastic limit to maximum load, and the ratio of elastic resilience to the total work which has to be done on the specimen to destroy it. That is to say, the useful 'play' energy for practical working stresses may be increased in some cases with resulting economy of material.

9. A comparison of the results of the tests on wrought iron and steel shows the great superiority of steel as compared with wrought iron for shafting.

10. The author, in conclusion, drafted a specification for torsion tests based on the results of the experiments given.

---

3. *A New Lifeboat.* *By* JAMES MITCHELL.

---

4. *An Outline of an Investigation now being conducted for the Dominion Government of the Coals of Canada.*[1] *By* Professor J. B. PORTER, *D.Sc.*

---

5. *The Development of the Grain Industry in the West and Grain Storage.*[1] *By* JOHN MILLER.

[1] Published in *Engineering.*

Section H.—ANTHROPOLOGY.

President of the Section.—Professor John L. Myres, M.A., F.S.A.

THURSDAY, AUGUST 26.

The President delivered the following Address:—

The Influence of Anthropology on the Course of Political Science.

Anthropology is the Science of Man. Its full task is nothing less than this, to observe and record, to classify and interpret, all the activities of all the varieties of this species of living being. In the general scheme of knowledge, therefore, anthropology holds a double place, according to our own point of view. From one standpoint it falls into the position of a department of zoology, or geography; of zoology, since man, considered as a natural species, forms only one small part of the animal population of this planet; of geography, because his reason, considered simply as one of the forces which change the face of nature, has, as we shall see directly, a range which is almost worldwide. From another point of view anthropology itself, in the strictest sense of the word, is seen to embrace and include whole sciences such as psychology, sociology, and the rational study of art and literature; since each of these vast departments of knowledge is concerned solely with a single group of the manifold activities of man. In practice, however, a pardonable pride, no less than the weighty fact that man, alone among the animals, truly possesses reason, has kept the study of man a little aloof from the rest of zoology. Dogmatic scruples have intervened to prevent man from ever ranking merely as one of the 'forces of nature,' and have set a hard problem of delimitation between historians and geographers. And the natural modesty of a very young science—for modern anthropology is barely as old as chemistry—has restrained it from insisting on encyclopædic claims in face of reverend institutions like the sciences of the mind, of statecraft, and of taste.

Yet when I say that anthropology is a young science I mean no more than this, that in the unfolding of that full bloom of rational culture, which sprang from the seeds of the Renaissance, and of which we are the heirs and trustees, anthropology found its place in the sunlight later than most; and almost alone among the sciences can reckon any of its founders among the living. This was of course partly an accident of birth and circumstance; for in the House of Wisdom there are many mansions; a Virchow, a Bastian, or a Tylor might easily have strayed through the gate of knowledge into other fields of work; just as Locke and Montesquieu only narrowly missed the trail into anthropology.

But this late adolescence was also mainly the result of causes which we can now see clearly. Man is, most nearly of all living species, the 'ubiquitous animal.' Anthropology, like meteorology, and like geography itself, gathers its date from all longitudes, and almost all latitudes, on this earth. It was necessary,

therefore, that the study of man should lag behind the rest of the sciences, as long as any large masses of mankind remained withdrawn from its view; and we have only to remember that Australia and Africa were not even crossed at all—much less explored—by white men, till within living memory, to realise what this limitation means. In addition to this, modern Western civilisation, when it did at last come into contact with aboriginal peoples in new continents, too often came, like the religion which it professed, bringing 'not peace but a sword.' The customs and institutions of alien people have been viewed too often, even by reasonable and good men, simply as 'y[e] beastlie devices of y[e] heathen,' and the pioneers of our culture, perversely mindful only of the narrower creed, that 'he that is not with us is against us,' have set out to civilise savages by wrecking the civilisation which they had.

Before an audience of anthropologists, I need not labour the point that it is precisely these two causes, ignorance of many remoter peoples, and reckless destruction or disfigurement of some that are near at hand, which are still the two great obstacles to the progress of our science. But it is no use crying over spilt milk, and I turn rather to the positive and cheering thought that the progress of anthropology has been rapid and sure, in close proportion to the spread of European intercourse with the natives of distant lands; and that its further advance is essentially linked with similar enterprises.

Anthropology and Politics in Ancient Greece.

Instances of what I mean are scattered over the whole history of anthropology. Philosophy, as we all know, begins in wonder; it is the surest way to jostle people out of an intellectual groove into new lines of thought, if they can be confronted personally and directly with some object of that numerous class which seems uncouth only because it is unfamiliar. The sudden expansion of the geographical horizon of the early Greeks, in the seventh and sixth centuries B.C., brought these earliest and keenest of anthropologists face to face with peoples who lived for example in a rainless country, or in trees, or who ate monkeys, or grandfathers, or called themselves by their mothers' names, or did other disconcerting things; and this set them thinking, and comparing, and collecting more and more data, from trader and traveller, for an answer to perennial problems, alike of their anthropology and of ours. Can climate alter character or change physique, and if so, how? Does the mode of life or the diet of a people affect that people's real self, or its value for us? Is the father, as the Greeks believed, or the mother who bore them, the natural owner and guardian of children? Is the Heracles whom they worship in Thasos the same god as he whose temple is in Tyre? Because the Colchians wear linen, and practise circumcision, are they to be regarded as colonists of the Egyptians? or can similar customs spring up independently on the Nile and on the Phasis? Here, in fact, are all the great problems of modern anthropology, flung out for good and all, as soon as ever human reflective reason found itself face to face with the facts of other human societies, even within so limited a region as the old Mediterranean world.

And I would have you note that these old Greek problems, like all the supreme problems of science old and new, were not theoretical problems merely. Each of them stood in direct relation to life. To take only cases such as I quoted just now from the Father of History—is there, for example, among all the various regions and aspects of the world, any real earthly paradise, any delectable country, where without let or hindrance the good man may lead the good life? Is there an ideal diet, an ideal social structure, or in general an ideal way of life for men; or are all the good things of this world wholly relative to the persons, the places, and the seasons where they occur? I do not mean that the ancient Greeks ever found out any of these things, for all their searching; or even that all ancient seekers after marvels and travellers' tales were engaged consciously in anthropological research at all. I mean only this: that the experiences, and the problems, and the practical *end* of it all, were as certainly present to the minds of men like Herodotus and Hippocrates, as they have been in all great scientific work that the world has seen.

In the same way it has for some while been clear to me that neither Plato nor Aristotle, the great outstanding figures of fourth-century Greece, was constructing theories of human nature entirely in the air. Their conceptions both of the ideal state of society, and of the elements which were fundamental and essential in actual societies as they knew them, were determined to a very large extent by their observation of real men in Sparta, Persia, or Scythia. But it is also clear that much that had been familiar to the historians of the fifth century, and particularly to Herodotus, had fallen out of vogue with the philosophers of the fourth. Systematic clearness had been attained only by the sacrifice of historic accuracy. Thucydides, in fact, standing right in the parting of the ways between history and rhetoric, might fairly have extended his warnings to a dissociation of history from political philosophy, which was just as imminent.

Anthropology and the Renaissance.

At the Revival of Learning it was the same as in the great days of Greece. New vistas of the world were being opened up by the voyagers; new types of men, of modes of life, of societies and states, were discovered and described; new comparisons were forced upon men by new knowledge crowding thick into their minds; and new questions, which were nevertheless old as the hills, made eddies and rapids in the swift current of thought, and cried out for an answer. Take the central political problems for example: What constitutes the right to govern, and what is the origin of law? In mediæval Europe this was simple enough. The duke, or the king, or the bishop governed by authority of the emperor, or the pope; and pope and emperor ruled (like Edward VII.) 'by the Grace of God.' Yet here, in Guinea, in Monomotapa, in Cathay, and in Peru, were great absolute monarchies which knew nothing of the pope or the emperor, and were mighty hazy about God. Yet their subjects obeyed them, and gave good reasons for their obedience, and chiefest of their reasons (as in all times and places) was this: 'We should be much worse off if we didn't.'

Unsocial Man and the Pre-Social State.

It would take me very far afield if I were to try to show how this universal answer came to change its ground from politics to anthropology, so that to the question—how men knew that they would be much worse off if they didn't—the answer came, that 'once upon a time they *had been* much worse off, *because* they didn't.' For my present purpose it is enough to note that, in all ages, philosophers who set out to define the *nature* of the State, have become involved in speculations about its *origin*; that historians, in their researches into its origin, have been forced into conclusions as to its nature; and that in both cases every belief about the Nature of the State has been found to involve a belief about a State of Nature; an answer of some kind, that is, to the question whether man was originally and naturally a social animal, or whether at some early period of his history he became social and domestic. In the latter event, how was domestication effected, and what sort of thing was undomesticated man? In the ancient world, after long controversy, Aristotle's definition of man as the 'social animal' had carried the day, and ruled that question out of court. But at the Revival of Learning, the unnatural behaviour of certain actual societies towards their individual members had revived irresistibly the whole question whether society was part of the natural order at all, and not a 'device of the heathen,' a mistake or a *pis aller;* and whether, if society was not thus 'natural,' men would not really be better off if they returned to their natural, pre-social, *unsocial* state, and began again at the beginning, to work out their own salvation. This belief in a pre-social state played a large part in the political philosophy of the seventeenth and eighteenth centuries; and conversely it was the very fact that the pre-social state as a philosophical conception fell out of vogue at the beginning of the nineteenth, which has distinguished modern political philosophy so markedly from its predecessors.

Now it is impossible to compare the successive presentations of the pre-social state without being struck by the widely different content of them. But how was it that the conception of a pre-social state of man, whether conceived as a

period of prehistoric development or as the result of a psychological analysis of mankind in society, assumed in different writers such widely different forms, and led—as was only natural—to such widely different proposals for the remedy of actual grievances? Why should Hobbes, for example, describe the life of the natural man as little better than a hell upon earth, 'no arts, no letters, no society; and (which is worst of all) continuall feare, and danger of violent death; and the life of man solitary, poore, nasty, brutish and short'; 'no property, no dominion, no Mine and Thine distinct, but only that to be every man's, that he can get; and for so long as he can keep it.' How comes it that Locke, whatever else he may deny his natural man, at all events reserves to every man, even in his first 'Treatise on Government,' property in his own person, and (as a corollary to this) property in the products of his labour, while in his second 'Treatise' he contemplates also a natural property in agricultural land? How comes it, again, that Montesquieu bases the whole fabric of civilisation upon the timidity of pre-social man; while for Rousseau it is the utter fearlessness of the savage which most distinguishes him from the craven members of societies? Flat contradictions of this sort, between thinkers who were almost contemporaries, and who agree so closely in the form and system of their reasoning, clearly result not so much from any defect of method as from some discrepancy in the data which the method was employed to explain. The question, therefore, begins to assume another shape: Whence did those political philosophers, whose theories involved a state of nature, get their respective data as to the character of natural man?

It is common knowledge, of course, as I have hinted already, that each thinker's own view of the nature of society went far to determine his imagination of its origin; and that his view of its nature was itself suggested by the political stresses of his own time. Hobbes, for example, writing in the middle of the Great Rebellion, was searching for a Sovereign, whose mandate should be beyond dispute; Locke, standing in even closer relation to the Revolution of 1688, was explicitly replying to the advocates of a Divine Right of Kings, and insisting that the Contract is revocable; Rousseau, confronted with iniquities which resulted from an antiquated distribution of privilege, is all for equality and fraternity as the necessary guarantees of liberty.

But it is possible also to put the sequence in the reverse order, and to make the inquiry, how far each thinker's conclusions as to practical politics resulted from his view of the nature of the State; how far his view of its nature is deducible from his beliefs as to its origin; and how far his beliefs as to the origin of society were themselves rendered almost inevitable for him, by the state of contemporary knowledge of the more primitive specimens of mankind and of the State itself.

The 'Geographic Control' of the Renaissance.

That such a line of reasoning was not foreign to the political thinkers of the seventeenth and eighteenth centuries is clear from a variety of considerations. In the first place, the whole movement in political philosophy, which is in question, stands, like the political events with which its turning points are so closely connected in point of time and personality, in the closest relation with a larger contemporary movement of scientific inquiry, of which the inquiry into the antecedents of society and of man is only one special, departmental, and relatively late application. And in the larger sphere, also, a general advance of physiographic theory had gone hand-in-hand with active physiographic discovery. Bacon's enlargement of current ideas of scientific method stands, as we all know, in the closest historical connection with the discovery of a new world by Columbus, and with the new prospects of exploration within the old world which were opened by Vasco da Gama. It would therefore be natural to expect that Hobbes, for example, should reflect in his 'Leviathan' the current conceptions of what *pre*-social man would be like, as inferred from the behaviour and circumstances of *un*social man as reported by contemporary voyagers.

Two great events of this time, in particular, set the study of mankind, no less than all the physical sciences, on a new pinnacle of outlook, and challenged all the theories of the Greeks and Arabians which had done duty at second-

hand, to explain the universe, since the great days of Alexandria. First, the discovery of the Cape route to the East threw open to European observation vast tracts of country and an immense number of societies of men whose fame indeed had come down through Pliny and Ptolemy, but whom no one but a few traders and missionaries had visited in person, since the Arab and the Turk tore East and West asunder and began to keep them so. Then, within the same generation, the discovery of America opened up, literally, a new world, wherein (among many marvels) one of the things which impressed its explorers most vividly and constantly was the presence of varieties of men whose mere existence shook Adamite theories of mankind to their foundation; who utterly failed to conform to the traditional requirements of the Flood, and professed inveterate ignorance on that subject; and whose manners and customs—when indeed they seemed to have any—betrayed a culture, or a lack of culture, totally unlike anything which the old world yielded, even taking into account the barbarous *Terra Nigritarum* which lay between the Canaries and India.

Thus almost at one gift three new sets of human documents were presented to the philosophers of Europe: (1) first-hand knowledge of the famous empires and kingdoms of the civilised East, of India, China, and the parts of 'India beyond the Ganges,' as the saying was, beyond the desert belt of Asia; (2) fresh access to the black men, south of the desert belt of Africa; (3) the discovery, beyond the no less desert ocean, of new and Western 'Indies,' peopled by wholly un-Indian tribes, whose aspect was Tartar rather than Indian or Malay, and whose behaviour seemed all the more inexplicable because it differed totally from what was expected so surely by the geographers.

Bodin, 1577.

It was long before this mass of new material could be compared and applied by the philosophers at home; but it was collected and recorded with avidity, and the insatiable demand for books of travel spread it broadcast, and made it sink deep into popular imagination. Still, with all his learning, even Bodin, writing in 1577, 'Of the Lawes and Customes of a Common Wealth,'[1] hardly shows by an allusion that he appreciates the new age that has dawned. There is a wonderful chapter, indeed, at the beginning of his fifth book, which is thus entitled: 'What order and course is to be taken to apply the form of a Common Wealth to the diversitie of men's humors, and the meanes how to discover the nature and disposition of a people.' Its contents show clearly what contribution he hoped to make to the art of statecraft, and also what was to be his method of research, to extract the truth from the mass of conflicting instances. It contains the whole pith and kernel of modern anthropo-geography, and completely anticipates the ethnological work of Montesquieu; but the data upon which it is based are with a single exception such as would have been available before the fall of Constantinople. His climatic contrasts are based on the Ptolemaic geography; he betrays no knowledge of a habitable south-temperate zone, and argues as if the world broke off short at the Sahara. It is only by a curious afterthought, which superposes on his classification of environments from arctic North to tropic South, a cross-division by grades of culture from civil East to barbaric West, that he betrays any hint that his cosmography has been disturbed by the new age of exploration. 'The Spaniards have observed,' he says, 'that the people of Sina (China), the which are farthest Eastward, are the most ingenious and courteous people in the world; and those of Brezill, which are farre Westward, the most cruell and barbarous;'[2] so that East goes with South, and West with North, and Bodin's cultural equator begins to lie askew between them; and we should note that the crucial instance here supplied by 'those of Brezill' is his single glimpse of Columbian man.

He has, indeed, full grip of the doctrine of a pre-social state, and of the application of inductive proof to support it; but his instances are exclusively

[1] I quote from the English edition of 1605, 'out of the French and Latin copies done into English by Richard Knowlles, Author of the Turkish History.'

[2] *Loc. cit.*, English Ed., 1605, p. 562.

derived from classical authors. 'He that would see,' he says,[1] 'what force education, lawes, and customes have to change nature, let him look into the people of Germanie, who in the time of Tacitus the Proconsull had neither lawes, religion, knowledge, nor any forme of a Commonweale; whereas now they seeme to exceed other nations in goodlie cities and well peopled; in arms, varieties of arts, and civil discipline.' A curious exception goes far to establish this rule. The only instance which I can recall, in which Bodin refers to an event in Negro-land, is where he illustrates the revolt of the Mombottu Negroes against the Moors in 1526 (p. 555); but this was an event, the news of which certainly reached Europe by way of the Morocco ports, not by way of the southern route, or westward down the Gambia; it was also one which made a great sensation in Europe, and was still a commonplace of cosmographers and moralists a generation later. In illustration of this I quote as follows from Peter Heylin's 'Microcosmus'[2]: 'The last Moroccan governor, Soui Halin, was slaine by Ischia, Anno 1526, and the negroes againe recovered their long lost liberty: instituting divers kings, and among others, Ischia was worthily made king of Tombutum. After this advancement, he quickly united many of the weaker kingdoms to his owne, which at this day is the greatest of the foure in whose hands kingly authority remaineth.' This actual example of a 'Leviathan' in process of construction was thus in text-book use in 1577, a generation before the time of Hobbes.

Shakespeare's Caliban.

The trend of popular opinion at the end of the sixteenth century, as to the characteristics of the state of nature, could hardly be better illustrated than by the Shakespearean conception of Caliban, 'solitary, nasty, and brutish'; barely human, in fact, but for his vices; living 'like a bear' (as Montesquieu so often puts it), grubbing roots and plundering bees' nests; a prey to panic, haunted by the spirit of the power of the air, and instinctively appeasing him, as savages do, by abstinence, abasement, and offerings. Mr. Hartland has only lately called attention again to the truth of detail with which Caliban is portrayed, and Mr. Sidney Lee has gone at some length into the question of his probable originals. No doubt there is in Caliban a touch of the gorilla pure and simple; and a touch of the gorilla's own brother, the 'Salvage Man' of heraldry and mediæval legend; Linnæus and Blumenbach, in fact, quote several examples of such 'wild men of the woods' who had been captured in various parts of Europe, and described in books before Shakespeare's time. But apart from his make-up—which, in the Globe Theatre (as at Her Majesty's), was mainly to tickle the gallery—Caliban is certainly neither ape nor idiot. He has his own code of conduct (when he can bring himself to conform to it); he knows when he has done wrong; and in his treatment of his invaders, of his small belongings, and in particular of his island property, he corresponds too closely with the current sixteenth-century descriptions of the feckless, passionate 'child of nature' to be set down as anything else but an experiment in the portrayal of natural man. And if we once view Caliban from this standpoint, it becomes almost incredible that he should have preceded Hobbes' sketch of the state of nature by nearly half a century, unless Hobbes' portrait itself was based upon a type already widely current, and generally accepted in popular belief.

Edward Grimstone, 1615.

I come now to a work of which I would gladly have further information. It is entitled 'The Estates, Empires, and Principallities of the World'; it was published in London in 1615, and it is described as having been 'translated out of the French by Edward Grimstone,' doubtless the translator of Joseph Acosta (1604) and Jean François Le Petit (1608). I introduce this work here for three reasons. It contains a fuller application of what I shall best summarise as Baconian methods to political science than is easily to be found elsewhere.

[1] *Loc. cit.*, English Ed., 1605, p. 565.
[2] I quote the Oxford edition of 1636, p. 722.

It shows very clearly that by this time the new discoveries were already being applied systematically to philosophical ends. And it illustrates a remarkable series of coincidences of discovery which in less than a generation were to have a profound effect on European thought.

The treatise consists of a collection of studies of human societies—συνηγμέναι πολιτεῖαι, as Aristotle used to call them—which professes to be complete. Its title-page, engraved by 'Ren. Elstracke,' is of a cosmographic type which descends, for example, into the title-page of Heylin's 'Microcosmus' a generation later; but which is seen here in its pristine glory. Four female figures, emblematic of Europe, Asia, Africa, and America, advance to do homage to James I., who sits enthroned, as he sits on Bodley's Tower in Oxford; and below are four posed warriors, in the weapons of their countries. America is represented by an obvious Aztec warrior in a peaked cap and coat of mail; but of the four women, America alone is nude: even Africa is partially draped in a mantle. The distinction is significant, for though Europe, Asia, and Africa all contribute to the contents of the book, America provides no example of a constitution at all: if it had any human inhabitants, they were, for Edward Grimstone, in a 'pre-social state.'

A few examples will illustrate sufficiently Grimstone's style and method, his attitude towards the new and the older learning, and his obvious debt to Bodin and to contemporary geographers. His preface censures alike the mere complacent patriots 'so farre in love with themselves as they esteeme nothing else, and think that whatsoever fortune hath set without the compasse of their power and government, should also be banished from their knowledge'; and the mere politicians who 'remain so tied to the consideration of their owne Commonweale as they affect nothing else, carrying themselves as parties of that imperfect bodie, whereas in their curiositie they should behave themselves as members of this world.' 'But there are others,' he goes on—and here his lash falls on the rigidly classical humanists of his own day—'which lie grovelling in the dust of their studies, searching out with the sciences the actions and manners of the Ancient, not respecting the Moderne, and they seeme so to admire the dead, as they have no care for the living.' What the classicists lack, he goes on to explain, is the 'Science or knowledge of the World,' a good part of which knowledge 'is comprehended in the discourse of this book.' And so 'although my chief desseigne was to deal onely with politicke and civile matters, yet to the end they might find all together, and not be forced to seeke for the description of countries whose custome I represent, I have made the corographie,' which in the next generation Peter Heylin defines as the 'exact description of some Kingdom, Countrie, or particular Province of the same.' But after describing thus 'all that the countrie yeields and the beasts that naturally live there and have their breeding,' he adds 'yet all this were little . . . if I should not show you the man which dwells in evere countrie, and for whom all those things seem to have been made, first in his ancient posture, and with his old customes, either altogether or for the most part abolished, then in his modern habit . . . to the end that every man may judge which is the better of the two Estates, and make use of part of the one and part of the other, having carefully ballanced the most considerable particularities of both.' He then explains that he must take account of their economics, their means of self-defence, and their religion, 'whereof I have discoursed, to show that it is the feare of some divinitie which maintaines people in their duties, makes them obedient to their princes, and diverts them much more from all bad desseignes than armes and souldiers which environ and threaten them. I do it also to show that whereas religion wants, of what sort soever it be, policie and order faile in like manner, and barbarisme, confusion, and rebellion, reign there in a manner continually, whereas they that seise on them should presently settle in their rude minds the apprehension of some power over all to dispose of things at pleasure.'

Here there is certainly a remarkable anticipation of a well-known passage of the 'Leviathan'; only the point of view is different, and the cynicism of Hobbes is well away.

Grimstone was well aware that he stood at the opening of a new period of discovery. 'I protest with trueth that if I have given any ranke or commenda-

tion to this worke, I will give much more to those that shall labour to make it perfect, and that any man may adde something dayly unto it, for that from time to time they have more certaine advice from all parts, especially from those countries which have not been much frequented, either by reason of the distance, or for their barbarousnesse.' For his own part, however, he had clearly done his best with the materials which he had. The 'Order of all the Estates contained within this booke' includes (besides all European states) 'the kingdomes of Tartary, China, Japan, Pegu, the Great Mogul, Calicut, Narsinge, and Persia; the Turkes Estate in Europe, Africke and Asia (including the ancient kingdomes of Egypt, Judaea, Arabia, &c.), the empire of Presbiter John, the Estate of the King of Monomotapa, the realme of Congo, and the Empire of Morocco'; and consequently was very fairly abreast of the travels and compilations of the day. His frank confession, therefore, that he knows only this, and wishes to know more, coupled with his total neglect of America, suggests that there may be real significance in the nude American on his title-page; and that America was not regarded as offering any regular constitutions.

Now it is certainly remarkable that, with the exception of a few European republics, all the 'Estates, Empires, and Principallities of the World,' which the author thinks worth describing, and in particular all the non-European states are personal monarchies of more or less absolute type: and this from a man who is expressly throwing classical and mediæval experience to the winds, and setting out to describe men as he finds them.

Peter Heylin and the Cosmographers.

Nor is this peculiarity confined to Grimstone's treatise. The standard English cosmography of the early seventeenth century is that of Peter Heylin, the learned, witty, and pugnacious chaplain of Archbishop Laud. Its method of treatment is closely modelled upon that of Grimstone; the sequence of topics is the same, and there is a good deal of matter common to the two, though Heylin of course is far more encyclopædic in his treatment, and includes many regions and 'estates' which do not occur in Grimstone. Here, too, with hardly an exception, the constitutions which are described are despotic; and as in Grimstone, particular attention is given to the brutal kingships of Western and Southern Africa. Almost the only exceptions are the cases where the royal power is not yet fully established, and others in which, to the best of Heylin's knowledge, there is no settled form of government.

In fact, if an unprejudiced inquirer were to attempt, with only the materials available in Heylin's time, to generalise as to the political evolution of the Old World outside Europe, I do not see how he could fail to arrive at the conclusion, *first*, that the natural and primitive state of man was, in the words of Hobbes, 'poor, nasty, and brutish; in continual feare, and danger of violent death'; and *secondly*, that wherever man had emerged from this primitive condition it had been by submission, more or less voluntary, and more or less by way of a *pis aller*, to an absolute despotism, usually exercised by a single imperial master who, like Ischia of Tombutum, had superseded by common consent a number of smaller despots.

Thomas Hobbes.

Hobbes himself does not often make mention of ethnographic matters. His outlook is, of course, primarily political, and his analysis, so far as it is not political, is psychological. Moreover, he is reticent throughout as to his sources. Now and then, however, he does lift the veil, and betrays an interest in the reports of travellers, and even a certain dependence on them.

On the vexed question of the 'naturalness' of patriarchal rule, on which Hobbes differs as violently as usual from the current Aristotelianism, his general attitude, though not positively that of an anthropologist, is at all events in agreement with the contemporary trend of observation. 'When the parents are in the State of Nature,' he says, 'the dominion there over the child should belong equally to both; and he be equally subject to both; which is impossible, for no man can obey two Masters.' In civilised states, he goes on the law decides

whether the father's claim or the mother's shall prevail; 'but the question lyeth now in the state of mere nature; where there are supposed no lawes of matrimony; no lawes for the education of children; but the Law of Nature, and the natural inclination of the Sexes one to another, and to their children.' 'If there be no contract,' he adds, 'the dominion is in the mother,' and this for the same obvious reason as Heylin had given already for female sovereignty in Borneo.[1]

It may be admitted at once that Hobbes' normal attitude of opposition to the Aristotelian tradition is such that the mere fact that Aristotle had laid down that 'the father is naturally in authority over the sons' may be held sufficient reason why Hobbes should decide for the Matriarchate. But it is certainly an instructive coincidence—and for my own part I am inclined to regard it as more—that the first great groups of matriarchal folk to be studied in any detail were precisely in areas now being thrown open by the discoverers: Southern India, Negro Africa, and North America; so that, at this period, matriarchal institutions, which had so long been treated as evidence of human depravity, or, at best, as curiosities and antiquities, were being rehabilitated for the first time in European thought as a practical scheme of society. Heylin had even generalised already that female kingships were correlated with tropical climate.[2] Once more the circumstances of the age and the general progress of knowledge were forcing on the notice of the philosophers fresh phenomena of a kind which precisely fitted the demands of the philosophic situation.

Most important of all, however, is the direct appeal of Hobbes to the evidence of discovery, when he is dealing with the State of Nature itself. 'It may peradventure be thought,' he says,[3] 'theare was never such a time nor condition of warre as this, and I believe it was never generally so, over all the world; *but there are many places where they live so now.* For the savage people in many places of America, except the government of small families, the concord whereof dependeth on natural lust, have no government at all, and live at this day in that brutish manner, as I said before. However, it may be perceived what manner of life there would be, if there were no common Power to fear, by the manner of life which men that have formerly lived under a peaceful government use to degenerate in a civill War.' Here, clearly, we have Hobbes the psychologist and politician supplementing his psychological and political evidence from a totally different quarter, and in particular quoting America as the last citadel of pre-social man.

To refer all Governments, as he explicitly does refer them, to the standard of Peru or Monomotapa; to imagine the State as a 'Leviathan,' a nightmare, a Frankenstein's monster, tolerable only because without it the life of man had been, and would be again, 'solitary, poore, nasty, brutish, and short,' was indeed but a partial inference from the life of 'natural man,' as it might have been constructed from evidence which was available even then. But it accords so closely with the accidents of contemporary discoveries, and with an actual tone of pitiful contempt which had come in fashion among the voyagers themselves, as to force the conclusion that Hobbes was really doing his best to state what nowadays we should call the 'most recent conclusions of anthropologists' on a matter of practical concern, and that political science owes more than is commonly supposed to this attempt to define and interpret large new facts of human nature as the Age of Discoveries revealed them.

John Locke.

In the next generation the connection between physics and politics is even more strongly marked. Closely as Locke was allied, in his political aspect, to the leaders of the English Revolution, he is still more closely associated with the first administrators of the Royal Society, and that in more than one department. His 'Elements of Natural Philosophy' remain to show how near he

[1] Heylin, *Microcosmus*, Oxford, 1636, p. 830.
[2] *Ibid.*
[3] Hobbes, *Leviathan*, Ch. XIII.

stands to Newton and the physicists; his medical studies kept him in close touch with the chemists and anatomists, and gave him a rational psychology; and we shall see how intimately his psychological analysis is concerned with his general anthropology. On the other hand, his interest in exploration and travel was keen and continuous. It peeps out in his 'Two Treatises on Government'; it is evident in his 'Essay on the Conduct of the Human Understanding'; it is confessed in a striking passage of his 'Thoughts concerning Reading and Study for a Gentleman'; and it bears remarkable fruit in his Introduction to Churchill's 'Collection of Voyages,' published in 1704, which shows him thoroughly acquainted with a wide range of the writers best qualified to inform him of the recent discoveries in regard to unsophisticated man.

Thus the case of John Locke is rather clearer than that of Hobbes. Here, too, though what impresses at the outset is the dependence of his political theory upon the political needs of his time, yet side by side with this we have the same intimate connection between his politics and his psychology as is obvious in the case of Hobbes, and it is naturally therefore to his psychology that I turn first for indications of his method of work. And we have not to go far into the 'Essay concerning Human Understanding' before we have a good example of what I mean. In the third chapter he is following up his contention that there are no 'innate principles' in the mind by an argument to the same effect as regards moral, or, as he calls them, 'practical,' principles. Virtue is generally approved, he says, not because it is innate, but because it is profitable; nor do men's actions betray any such 'internal veneration of these rules.' Even conscience, which is usually represented as checking us for our breaches of them, cannot be distinguished, in the mode of its origin, from any other kind of human knowledge, and in many cases it is only 'from their education, company, and customs of their country' that men are persuaded that morals are binding on them; 'which persuasion, however got, will serve to set conscience at work.' Then comes the passage which concerns us now. 'But I cannot see how any men should ever transgress these moral rules, with confidence and serenity, were they innate and stamped upon their minds. Have there not been whole nations, and those of the most civilised people, amongst whom the exposing of their children, and leaving them in the fields to perish by want or wild beasts, has been the practice, as little condemned or scrupled as the begetting them?' Then follows a list, a couple of pages long, of barbarities practised by the Mingrelians of the Caucasus; the natives of the interior of Africa; the Caribbees of the Orinoco; a people in Peru (who fattened and ate the children of their female captives); and many others. Among the Tououpinambos, another American tribe, 'the virtues whereby they believed they merited Paradise were revenge and eating abundance of enemies; they have not so much as a name for God, and have no religion, no worship.' Among the Turks 'the saints who are canonised lead lives which one cannot with modesty relate.' 'He that will carefully peruse the history of mankind,' he concludes, 'and look abroad into the several tribes of men, and with indifference survey their actions, will be able to satisfy himself that there is scarce that principle of morality to be named, or rule of virtue to be thought on (those only excepted that are absolutely necessary to hold society together, which commonly, too, are neglected betwixt distinct societies), which is not, somewhere or other, slighted and condemned by the general fashion of whole societies of men, governed by practical opinions and rules of living quite opposite to others.'

Here, clearly, Locke claims to support, if not to found, his generalisation as to the nature of the human mind on a comparison of specific varieties of human behaviour. At the same time he makes definite exception of those principles which, as he says, 'are absolutely necessary to hold society together,' and these he is apparently inclined to regard either as actually innate or at all events as a higher order of universality than the ordinary principles of morals. It is the beginning of a deep distinction in anthropological theory, which bears fruit, long after, in Bastian's distinction between Universal and Racial Ideas.[1]

There are other passages in the 'Essay' in which the same argument is used,

[1] *Gemeingedanken* and *Völkergedanken.*

drawn from observation of actual savages. In Chapter IV., for example, he gives a long list of tribes whose members are devoid of the idea of God. 'Besides the atheists taken notice of among the ancients, and left branded upon the records of history, hath not navigation discovered, in these later ages, whole nations at the Bay of Soldania (in South Africa), in Brazil, in Boranday, and in the Caribbee Islands, &c., amongst whom there was to be found no mention of a God, no religion ?' He goes on to quote further evidence as to the Caiaquas of Paraguay, the 'Siamites' (which 'will I doubt not be a surprise to others, as it was to me'), and the Chinese. His authorities in this passage are ample: Sir Thomas Roe, the hard-headed English ambassador to the Great Mogul, and his French editor, Thévenot; de Choisy, for Siam; La Loubère, for Siam and China: Navarette and the Jesuit Relations, for China; Ovington, for Surat; Martinière, de Léry, and Nicholas del Techo. For South Africa, of course, he quotes Terry, and through Terry, the educated Hottentot Coore or Courwee, who came to England for a time, and of whom Heylin, too, has a quaint story to tell. And these are no mere gleanings from other people's fields. Few of Locke's contemporaries had a better right to an opinion in the department of knowledge which now we should call anthropology, and which formed already a principal department of geography. And he had the highest opinion of its importance, for in his 'Thoughts concerning Reading and Study for a Gentleman' he recommends a list of original books of travel which occupies more than a page. His own reading was enormous, and set him wholly free of compendia like those of Heylin and Moll, which indeed he could compare and criticise as an expert. By a comparison of the libraries of Christ Church, of the Bodleian, and of the Royal Society, it is easy to verify the general conclusion that if the English gentleman, as Locke feared, did not think it worth while to bestow much pains on geography, it was not for want of available books or of examples of distinguished publicists who were also good geographers. And this is of some importance to my general thesis, for it shows that in Locke's time still, as in the days of Hobbes and before, inductive anthropology and inductive politics were greatly in the air and were being studied together; and consequently that political philosopher, no less than a psychologist, was addressing a public which knew about savages and expected a thinker to take account of them.

It is time now to turn to the 'Two Treatises on Government.' Their form was, of course, mainly dictated by that of Sir Robert Filmer's 'Patriarcha, or the Natural Power of Kings,' in which the patriarchal theory of society, maintained with a thoroughness which would have delighted Aristotle, anticipates almost verbally the orthodox criticism which was levelled two centuries later at Maclennan and Lewis Morgan. Filmer's attitude in fact is exactly that of the Aristotelian and classicist thinkers castigated by Edward Grimstone. He can quote Athens, Sparta, Rome, and the Jewish patriarchs; he is learned about Nimrod and Codrus; but from beginning to end he writes as if America and the Cape route to India were still unknown. Locke has arguments enough, of a more relevant kind, to bring against Filmer, and makes no direct comment upon the narrowness of his experience of mankind; but implicitly his reply is precisely in that form. It is an appeal to experience against authority; to modern discovery in the new worlds beyond the oceans, against traditional accounts of ancient societies in the Mediterranean and the Semitic East. To refute Filmer's claim that Patriarchal rule is natural, he recalls the systematic fattening and eating of children by the Peruvians,[1] and quotes a long passage from de la Vega's 'History of the Yncas.' On the question of the authority of the law over an alien, the 'Indian' is his typical example. 'The legislative authority by which they are in force over the subjects of the commonwealth hath no power over him. Those who have the supreme power of making laws in England, France, or Holland, are, to an Indian, but like the rest of the world—men without authority.' [2]

Locke himself, indeed, was before long to be confronted with this question in a very practical shape; for it was he who was deputed to draw up a constitution for the new settlement of Carolina, the first British settlement which came into

[1] Ch. I. 57. [2] Ch II. 13.

direct contact with communities of agricultural Redskins of the Muscogean stock, and consequently one of the first to be confronted with any worse problems of expropriation than those which had been described by Heylin.[1]

In the very next section [2] he is confronted with another question of natural law on which the experience of the colonists was modifying opinion profoundly. 'It is not every compact that puts an end to the state of Nature between men, but only this one of agreeing together mutually to enter into one community and make one body politic: other promises and compacts men may make with one another, and yet still be in the state of Nature. The promises and bargains for truck, &c., between the two men in Soldania, or between a Suris and an Indian in the woods of America are binding to them though they are perfectly in a state of Nature in reference to one another; for truth and keeping of faith belongs to men as men, and not as members of society.' Here we have a clear anticipation of Montesquieu's position:[3] 'The law of Nature is naturally founded upon this principle, that the various nations ought to do one another as much good as possible in peace, and as little harm as possible in war, without damage to their true interests. . . . All nations have a law of nations. Even the Iroquois, who eat their prisoners, have one. They send and receive embassies; they recognise laws of war and laws of peace. The only trouble is that this law of nations is not founded on the right principles.' Montesquieu, it will be observed, recurs here, like Locke, to the 'Indian in the woods of America'; and we shall see presently that there is an historical reason for this prominence of the Redskin in such a context.

One of Locke's main advances upon the position taken up by Hobbes is in his treatment of the Right of Property.[4] 'Though the earth and all inferior creatures be common to all men, yet every man has a property in his own person. This nobody has any right to but himself. The labour of his body and the work of his hands we may say are properly his. . . . The fruit or venison which nourishes the wild Indian, who knows no enclosure, and is still a tenant in common, must be his; and so his—*i.e.* a part of him—that another can no longer have any right to it before it can do him any good for the support of his life.' Here Locke's ethnological position becomes clearer still. He is familiar with the hunting and berry-eating Redskin of the New England forests; but he is not yet brought into contact with the agricultural communities of the south-east; and still less is he aware of the paradoxical behaviour of the later-discovered Indians of the Chaco, where precisely that observance holds of which he denies the existence—namely, that the actual hunter has no recognised right to his game, and sits out,

[1] Heylin, *Microcosmus*, Oxford, 1636, *An advertisement to the reader concerning America in general.* 'He that travelleth in any Part of America not inhabited by the Europeans shall find a world very like to that we lived in, in or near the times of Abraham the Patriarch about three hundred years after the flood. The lands lie in common to the Natives and all Comers, though some few small parcels are sown, yet the Tiller claims no right in them when he has reaped his crop once. Their Petty Kings do indeed frequently sell their kingdoms, but that in effect is only the taking Money for withdrawing and going further up the Country, for he is sure never to want land for his subjects because the country is vastly bigger than the Inhabitants, who are very few in proportion to its greatness and fertility. . . . Sometimes whole Nations change their Seats, and go at once to very distant places, Hunting as they go for a Subsistance, and they that have come after the first discoverers have found those places desolate which the other found full of inhabitants. This will show that we have done them no Injury by settling amongst them; we rather than they being the prime Occupants, and they only Sojourners in the land: we have bought however of them the most part of the lands we have, and have purchased little with our Swords but when they have made war upon us.'

[2] II. 14. [3] *Esprit des Lois*, I. iii.

[4] Ch. V. 27. Though the 'Two Treatises on Government' were published simultaneously in 1690, it must be remembered that the first of them was written in reply to Filmer's tract of 1680, and bears evident marks of earlier composition. It was indeed already out of date in 1690; but for our present purpose it is this very circumstance which gives it value as evidence for the growth of Locke's knowledge and thought.

hungry and patient, until the whole society has had its fill. Locke proceeds accordingly: [1] 'Thus this law of reason makes the deer that Indian's who hath killed it. It is allowed to be his goods who hath bestowed his labour upon it though before it was the common right of everyone.'

His estimate of the agricultural skill of his 'Indians' was a low one.[2] 'An acre of land that bears here twenty bushels of wheat, and another in America, which with the same husbandry would do the like, are without doubt of the same natural intrinsic value. But yet the benefit mankind receives from one in a year is worth 5*l.*, and the other possibly not worth a penny: if all the profit an Indian received from it were to be valued and sold here, at least, I may say truly, not one thousandth.' Here again his experience does not extend yet to the agricultural communities of Carolina and Georgia; it is the rude husbandry of the Iroquois and Algonquins that is typical, for him, of the natural state of man. More generally still, when he speaks of the function and use of money,[3] he asserts: 'Thus in the beginning, all the world was America, and more so than that is now; for no such thing as money was anywhere known.'

His views on the natural estate of matrimony are coloured again from the same source. 'All the ends of marriage being to be obtained under politic government, as well as in the state of Nature, the civil magistrate doth not abridge the right or power of either [parent] naturally necessary to those ends'; a reflection once more of the many curious compromises between patriarchal and matriarchal government in American societies, and particularly among the peoples who had partially adopted agriculture—namely, the Southern Iroquois and the Eastern Sioux of Virginia. America, as we see from the extract on money, though it is still near the state of Nature, has in some parts advanced beyond it; but it is still to America that he turns for examples of more purely natural conditions: [4] 'If Josephus Acosta's word may be taken, he tells us that in many parts of America there was no government at all.' [5] 'There are great and apparent conjectures,' says he, 'that these men [in Peru] for a long time had neither kings nor commonwealths, but lived in troops, as they do this day in Florida—the Cheriquanas, those of Brazil, and many other nations, which have no certain kings, but as occasion is offered in peace or war, they choose their captains as they please.' [6] 'I will not deny,' he goes on,[7] 'that if we look back, as far as history will direct us'—he might well have added, as far as ethnology is any guide—'towards the original of commonwealths, we shall generally find them under the government and administration of one man. . . . Conformable hereunto, we find the people of America, who (living out of the reach of the conquering swords and spreading domination of the two great empires of Peru and Mexico) enjoyed their own natural freedom [to elect a monarch], though *ceteris paribus* they commonly prefer the heir of their deceased king; yet, if they find him any way weak and incapable, they pass him by and set up the stoutest and bravest man for their ruler.' Once more America supplies the typical instance, and (once more) that part of America which best satisfies Locke's description is among the hunting tribes of the Southern Algonquins, with their elective war-path chiefs, and regular deposition of the war-lord as soon as his physical force abates. Eventually the comparative argument is pressed home, with a hypothesis of the graduation of culture from East to West, almost in the manner of Bodin or Thucydides: 'Thus we see that the kings of the Indians, in America, *which is still a pattern of the first ages in Asia and Europe*, whilst the inhabitants were too few for the country, and want of people and money gave no temptation to enlarge their possession of land, or contest for wider extent of ground, are little more than generals of their armies; and though they command absolutely in war, yet at home, and in time of peace, they exercise very little dominion, and have but a very moderate sovereignty; the resolutions of peace and war being ordinarily either in the people or in a council, though the war itself, which admits not of pluralities

[1] § 30. [2] § 43. [3] § 49. [4] § 102. [5] § 102.

[6] Again he is quoting Acosta, *National and Moral History of the East and West Indies*, 1604, I. 25.

[7] § 105.

of governors, naturally devolves the command into the king's sole authority.'[1] Here, at all events, is a quite unmistakable sketch of the characteristic diarchies of the warlike tribes on the Appalachian chain and its Atlantic slope—Creeks, Cherokees, and the like: a type of constitution quite limited in geographical range, and exactly representing in its distribution the outskirts of European knowledge in Locke's day.

Robinson Crusoe.

I made use of Caliban as a popular anticipation of Hobbes; as a sequel to Locke I cannot do better than refer to the savages in 'Robinson Crusoe,' and particularly to Man Friday. This again is a composite portrait, the predominant features of which come from the piratical Caribs of the Brazilian coast, with their dug-out canoes, their simple weapons, their inveterate cannibalism. This Carib type represents quite a different line of observation from Locke's mainly Redskin evidence, and the novelty is the more important, since at the next turn of the wheel Rousseau makes just as free with this very word 'Carib' as Locke had done with his 'Indian in the forest,' or as Montesquieu was about to do with his 'Iroquois.'

So far as any other element besides Carib is recognisable in the savages of Defoe—and the portrait, as I have said, is clearly a composite one—it is another eighteenth-century type, the 'South Sea Islanders,' first popularised in England immediately before the appearance of 'Robinson Crusoe,' by the discoveries of William Dampier,[2] which were at the same time of great geographical importance, admirably described, and very widely read. They figure repeatedly, for example, in the footnotes of Montesquieu.

But the point in which Defoe's savages date his book and affect our present subject most clearly is in the psychology of Man Friday. In particular the dialogues between Crusoe and his man on such subjects as the existence of God, and other test questions of the day, are full of learning, and of ingenious, if partly humorous, parody of current psychology and of the State of Nature. But to develop this subject in detail would require a whole essay to itself.

French Canada: Sagard and Lafitau.

On French thought, meanwhile, as on English, the natives of North America had a very definite influence in the seventeenth century, though not quite in the same way as in England; for the natives whom the French encountered on the St. Lawrence were of a different stock, lived in a different latitude and climate, and enjoyed a very different culture. The French colonists also had come with different predispositions, and were struck by different characters in the order of things which they invaded. Here, as elsewhere, a foremost place must be given to the Jesuit reports; full and graphic records of native life and custom, which were widely read in France, as elsewhere, and have hardly been superseded even now. Another book which became classical was that of Gabriel Sagard,[3] which was well known to Locke, and is recommended by him, and was certainly a remarkable study of a barbarous people.

The full tide, however, of what I may call the Huron and Iroquois mythology does not come till the beginning of the next century. Another Jesuit missionary, Joseph Lafitau, produced, in 1724, a large work entitled 'The Manners of the American Savages, compared with the Manners of the First Ages.'[4] Lafitau had only been five years in Canada himself; but he had the acquaintance of Julien Garnier, who had been in the mission field for sixty years, and spoke Algonquin,

[1] § 108.

[2] Capt. William Dampier, *A New Voyage round the World, describing particularly the Isthmus of America*, 1697. It will be remembered that *Robinson Crusoe* appeared in 1719.

[3] Gabriel Sagard, *Grand Voyage au pays des Hurons.* Paris, 1632.

[4] Joseph Lafitau, *Mœurs des Sauvages Ameriquains comparées aux Mœurs des premiers Temps.* 2 vols. Paris, 1724.

Huron, and all the five dialects of Iroquois. Lafitau's personal experience was mainly among the Iroquois; he did not, however, confine himself to the Redskins of French Canada; he ranged as far as the Eskimo and the Peruvians, and put together an immense amount of information. For all his protestations to the contrary, Lafitau starts with a theory. 'I have not been satisfied to understand the character of the savages, and to make myself acquainted with their customs and practices. I have searched among these customs and these practices for traces of the most distant antiquity; I have read with care those of the most ancient writers who have treated of the manners, laws, and usages of the peoples with whom they had some acquaintance; I have compared these manners with one another, and I confess that while the ancient writers have given me lights on which to base some lucky guesses concerning the savages, the customs of the savages have given me light to understand more easily, and to explain, many things which are in the ancient authors.' He regards the Odyssey, for example, as a collection of sketches of primitive peoples, strung together on the thread of an interrupted voyage from Troy, but having as their object to recommend the study of ethnology. Manners, moreover, are to be studied to form—perhaps even to reform—manners, and also to reform people's ideas. 'I have seen,' for example, he says, 'with extreme pain, in the majority of the *Relations*, that those who have written of the manners of barbarous nations have depicted them as people who have no religious feelings, no knowledge of God, no object of worship; as people who have neither laws nor administration nor forms of government; in a word, as men who have little human about them except their faces. . . . I know' (he goes on) 'that in these latter days people have wanted to shake the proof of the unanimous agreement of the nations to recognise a Deity, as if this unanimous agreement could possibly be a mistake. But the sophisms and subtleties of some individual who has no religion, or whose religion is highly suspect, cannot shatter a truth which has been recognised by the Pagans themselves, which has been received from all time without contradiction, and which we can assume as an axiom.'

Having said that it is an axiom, Lafitau proceeds rather inconsistently to declare it his task to *prove* this unanimity of opinion among all nations, by showing that there is in fact no one so barbarous as not to have a religion and not to have morals. 'And I flatter myself that I make the matter so obvious that no one can doubt it, unless he wishes to be blind in the midst of light.'[1] He has a long chapter, also, on their form of government, again with one eye upon Locke. 'Of all the forms of government, that which has seemed to me most curious is that of the Hurons and the Iroquois, because it is most like that of the ancient Cretans and Lacedemonians, who had themselves preserved the longest the laws and usages which they received from the first ages of the world. Though this oligarchic form of government is peculiar to them, the manner of dealing with business is pretty general in all the states of barbarous nations; the nature of the business almost the same, as well as their public assemblies, their feasts and their dances.' His conviction that human nature is the same all the world over comes out again later on.[2] 'The time which I spent among the Iroquois has tempted me to describe their manners in greater detail, because I know them better and am more confident of what I assert. Nevertheless one may say that the manners of the natives in general are pretty much alike.'

We are here already in the middle of a reaction, on the one hand, against Locke's disproof of innate ideas, and, on the other, against the belief that the savages of the New World represent, in any essential, a lower stage of culture than is to be traced in survivals in classical antiquity. In fact, we are on the straight road to the noble savage as we get him in Pope's 'Essay on Man' (1733), which uses Lafitau freely. But we are also very much further still on the road to a synthetic ethnology. Locke had pointed the way, in his Thucydidean comparison of the modern Indian kings to the 'most ancient kings of Europe,' by which, presumably, he meant the Homeric Monarchy. When, therefore, the first curiosity and wonder began to subside, and the real similarity in the performances of human reason under similar circumstances began to be perceived, the foundations began

[1] Lafitau, i. p. 20. [2] Lafitau, i. p. 25.

to be laid for a fresh statement of the characteristics of non-social man. Whether the synthesis was to have a psychological or historical content was still a matter of uncertainty; but, in spite of all his eccentricities, I think we may count Lafitau as a pioneer of a new line of work. This at least he had of the pioneer; his book succeeded and was much talked of; he certainly influenced Pope and his English contemporaries, and in France he prepared the way for the decisive intervention of Montesquieu.

Montesquieu.

It is easy to examine in similar detail the sources of the ethnology of Montesquieu, who had of course a very wide range of reading, and evidently made good use of his English acquaintances, and his connection with the Royal Society, to keep himself well posted in current English exploration. He quotes Dampier and the 'Lettres Edifiantes' repeatedly; together with Hyde's 'Persia,' Chardin's 'Persia,' Pyrard's 'Turkey,' Bernier's 'Kashmire,' Perry's 'Russia,' Smith's 'Guinea,' Kaempfer's 'Japan,' and a number of other explorers; and he has the immense merit that he rises altogether superior to the current cant about Caribs and Hurons. I doubt whether either name occurs more than once or twice throughout the 'Esprit des Lois.' Montesquieu also goes far more nearly back to the geographical standpoint of Bodin than any of his predecessors or contemporaries.[1] If he does not, in fact, take rank as one of the founders of synthetic ethnology, it is because, like his great predecessor, he was inclined to overrate the influence of physical environment, and to neglect the human factor of racial momentum. But it is still for the future to show whether it is Montesquieu or the ethnologists who are in the right.

'Man, as a physical being, is governed' for Montesquieu 'like other material bodies, by invariable laws. As a rational being he is constantly breaking the laws which God has established, and changing those which he establishes himself.' He is made, that is, for a life *in society*. 'But before all these laws are those of nature, so called because they are derived solely from the constitution of our being. To understand them rightly we must consider what man was before the establishment of societies. The laws of nature will be those which he would obey in such a condition. Such a man would at first only be sensible of his weakness. His timidity would be extreme, and if we need experience of that, there have actually been found "wild men" in the forests: they are afraid of, and run away from, everything. In this condition, each one feels his own inferiority; at best, if at all, he feels himself an equal. He would never therefore attempt to attack, and peace would be the first law of nature.' At this point Montesquieu quotes 'Wild Peter,' to whom we must return before long, as a recent and notorious example of this kind of natural man. From this standpoint he goes on to attack Hobbes' idea of a natural man, aggressive and domineering, and concludes that, just as fear drives men to fly, so signs of *mutual* fear would soon tempt them to draw nearer; not to mention the natural pleasure which any animal takes in the society of its kind. His four 'laws of nature,' therefore, are (1) the sense of weakness; (2) the sense of hunger and desire to satisfy it; (3) the sense of mutual support; (4) the natural need of society in the sense of mere acquaintance. This last alone is purely human.

It will be seen at once that three of these are concerned merely with the maintenance of an animal life, and that, so far, Montesquieu is arguing on the lines of a purely zoological psychology. It will also be clear that in the fourth 'law of nature' he is either begging the question that man is a social animal, or else he is appealing to experience of actual human societies.

Montesquieu does not leave us long in doubt which is to be his line of argument. In the very next chapter he argues that, 'as soon as men are in association they lose the feeling of weakness; the equality which existed between them ceases, and the state of war begins. Each separate society comes to feel its strength, and this produces a state of war of nation against nation.' For there must be different peoples. This last point, however, he does not attempt to prove.

[1] See particularly Book XIV., *Of Laws in their relation with the nature of the Climate*, where his geographical learning is most displayed.

Therefore there arise laws, in the relations in which these nations stand to one another; and these are the 'Law of Nations'—the *Jus Gentium*. 'All peoples have a law of nations. *Even the Iroquois*, who eat their prisoners, have one. They send and accept embassies, they recognise laws of war and laws of peace. The only trouble is that *this* law of nations is not founded on the right principles.'

Here, then, as was by this time inevitable for a Frenchman, Montesquieu is once more face to face with the Iroquois. Their 'Law of Nations,' it is true, 'is not founded on the right principles'; but a law of nature they have got; and this is his proof that there *is* a law of nature. But clearly he only proves this if we are to assume that the Iroquois are in the state of nature; or at any rate so near to it as to be a fair sample of what human behaviour would be, untrammelled by any positive or non-natural law.

Montesquieu, therefore, like his predecessors, not only takes full account of recorded observations of barbarous peoples, but is directly and specifically guided in his argument by the 'last new thing' in current anthropology, the Iroquois of French Canada, as revealed by Lafitau in 1724.

Rousseau.

Rousseau, I need hardly say, remains something of a puzzle. Like his predecessors, he comes at the subject of the State of Nature, in the first instance, as a reformer and a political philosopher; and I am bound to say that it is only in proportion as he feels the need of illustration, and realises that his whole case is hypothetical, that he is driven back upon ethnology as an ornament of style and as a makeshift for proof. Unlike his predecessors, however, he cannot be given credit for great learning on the point at issue, and he frankly admits as much:—'As we know so little of Nature and agree so ill as to the meaning of the word Law, it would be difficult to settle on a good definition of the Law of Nature.' There was, however, a great deal known about 'Nature' in 1753 which was not in Rousseau's philosophy. Yet he had clearly read travels, as everyone did in those days, and he reproduces a few details as to the qualities and customs of savages.

He quotes Peron's 'Voyages aux Terres Australes' for the comparative strength of Europeans and Tasmanians, and illustrates sensory acuity from Hottentots and Redskins; but his favourite type is the Carib, whom we have already met in discussing Defoe. It is the 'Carib of Venezuela' who shows such surprising skill in tackling wild animals; it is, too, 'the inhabitant of the banks of the Orinoco,' who learned the use of 'those boards which he applies to the temples of his children, and which assure to them at least part of their natural idiocy and happiness.' It is the 'Carib' again who 'sells his cotton mattress in the morning and comes with tears in the evening to buy it back, for lack of foresight that he was going to want it for the coming night,' and whose happiness is, nevertheless, so quaintly compared with that of a European Minister of State. There is a curiously Amazonian flavour, meanwhile, about Rousseau's sketch of the primitive family. 'The most ancient of all societies, and the most nearly natural, is that of the family. But even here the children do not stay bound to the parent any longer than they need him for their own maintenance. As soon as this need ceases, the natural tie dissolves. The children, released from the obedience which they owed to the father, the father released from the care which he owed to the children, all return equally to independence. This common liberty is a consequence of human nature.' Such an analysis is, of course, only true in fact under the conditions of a tropical forest. Nowhere else does the family tie break down in the way Rousseau describes; and nowhere was this type of social anarchy more open to study than in the equatorial forests of South America.

Whence did Rousseau acquire his conception of the Carib? The most obvious source would be the seventeenth volume of the Abbé Prévost's 'Histoire Générale des Voyages,' which contains a full summary of the 'Origin, Character, and Customs' of the Caribs, and a narrative of European colonisation of the Antilles; but this volume does not seem to have been published till 1761. Raynal's 'Histoire Philosophique et Politique des Etablissements et du Commerce des Européens

dans les deux Indes,' published in Geneva in 1781, is also too late; but Raynal in particular had a wide acquaintance, and his ideas were current in French society long before his book came out; so we are probably safe in crediting Rousseau with at all events a gossiping acquaintance with a type of savagery which was enjoying a considerable vogue in his time.

'Wild Peter.'

Both Rousseau and Montesquieu were, of course, also in a position to enjoy the perplexities of the advocates and assailants of the doctrine of innate ideas when a real live specimen of *Homo sapiens ferus* turned up in the Hanoverian forests in the year 1724. The story of 'Wild Peter' is probably familiar reading, but though the literature which this poor creature provoked is in parts diverting both to the anthropologist and to the philosopher, I should encumber my story unduly if I digressed. Montesquieu, having been in England and having his friends in London, has not very much to say; but Rousseau gives 'Wild Peter' a long note, and was evidently considerably impressed.

The South Sea Islanders.

Rousseau wrote just too early to be able to make use of what must have appeared to his contemporaries a remarkable confirmation of his view of the State of Nature—namely, the discovery by Cook, Bougainville, and La Pérouse of the Polynesian Islanders. But this discovery, coming as it did so closely after Rousseau's manifesto, and so markedly confirming certain phases of his sketch, seems to have attracted some attention and to have been given more than its due weight. For it came, at all events to the public mind, as the revelation of a new type of Man and Society, still more remote from contact with the modern world even than the Carib and the Iroquois, still more likely therefore to have withstood the attacks of reason, if not of time, and consequently to have preserved some traces of the original State. The South Seas had, of course, been traversed cursorily since the days of Magellan; Dampier had done much to make their natives known; and I have indicated the share which his work may have had in forming the portrait of Man Friday. But it was not till after the publication of Rousseau's 'Discourse' that the significance of these data was appreciated; and ethnology owes much in this instance to philosophy for the impulse which was given, in the generation which follows, to the study of 'Pacific Man,' in more senses than one; though I think the debt is in part repaid when we see what Herder owes to ethnology.

The Pacific Islanders, of course, with their Garden of Eden existence, challenged all preconceived notions of the defective mentality of races remote from Europe, and effected an almost Copernican revolution in the self-centred ethnology of the discoverers. If a South Sea Islander like Omai could pick up English, play chess, and behave like a gentleman after a few months' consort with Europeans, there could not be much amiss with his 'mind'; and it was clearly time to amend current conceptions as to the identity of the primitive with the remote.

George Forster, for example, who wrote the first really philosophical account of the voyages of Captain Cook, with whom his father had sailed as one of the chief naturalists of the expedition, was completely convinced by his experiences that the Biblical record was true after all, and that the primitive state of man was a state of innocence and happiness. It was a reaction against the ideas of Hobbes, Locke, and Montesquieu, which went far beyond what was contemplated even by Rousseau, and it did more to retard the progress both of anthropology and of general biology than anything else in that century.

So long as the sentimental enthusiasm aroused by Rousseau persisted, there was little hope of advance in the direction of a solid ethnology. But in England the contagion was slighter, the contact with the facts of exploration closer, and the reaction earlier; and Germany too was already well awake, with Herder, almost before the Revolution was ablaze.

'I take this opportunity,' writes Chamisso, who had himself been in the

Pacific in 1815–18,[1] 'to protest most vigorously against the term savage in its application to the South Sea Islanders. I prefer, so far as I can, to connect definite ideas to the words which I use. A savage for me is the man who, in the absence of fixed abode, agriculture, and domestic animals, knows no form of property but his weapons, with which he maintains himself by the chase. Wherever the South Sea Islanders can be accused of corruption of morals, this seems to me to bear indication not of savagery but of over-civilisation. The various inventions, coinage, writing, and the like, which are appropriate to mark off the different degrees of civilisation which the peoples of our continent have attained, cease to afford under conditions so different any standard for the insular and isolated stock which lives under this happy sky, without yesterday or to-morrow, living for the moment, and for pleasure.'

Voltaire.

I must leave out of consideration here the results of these successive pictures of the Pre-Social State on the course of Political Philosophy. All I am concerned to do here is to give reasons why these different conceptions took the particular shape that they did, under the several circumstances of the age which gave birth to them; and I hope that I have been able to show that one of the principal factors which determined their form was the actual state of anthropological knowledge in the years which immediately preceded the publication of each.

A good example—if this were the time to develop it fully—is the very entertaining controversy between Rousseau and Voltaire over the psychical unity and uniformity of Man. What led Voltaire to so totally opposite a conception of the state of Nature to that entertained by Rousseau? Partly, of course, his own political and philosophic standpoint, with which we are not concerned directly here; but partly also the circumstance that in the years which immediately preceded his attack upon Rousseau, the learned world of Europe—and learned France in particular—had come under the influence of a fashion—I might almost call it a craze—of enthusiastic admiration of China and things Chinese. The Jesuit Missions to China, in particular, had been sending home wonderful accounts of the civilisation of the Chinese, and fabulous versions of its antiquity; and it was, of course, common knowledge in Europe in the eighteenth century that any civilisation which went back into the second and third thousand years B.C. must be in respectably close contact with the Origin of Man, and therefore might be expected to reflect at close quarters the outlines of the original state. To find, therefore, that this immemorial civilisation of China had existed apparently unchanged since its first ages, was to discover fresh light on the nature of Man and a new glimpse of primitive society. By this revelation of China, it is true, the Pharaoh's heart of the *ancien régime* was hardened in pursuit of what has come down into our vocabulary as *chinoiserie*; and, by a strange irony, one of the acutest critics of that *régime* was furnished from the same source with a fresh instrument of proof of the essentially social nature of Man in reply to the Nihilism of Rousseau. 'Do you mean by "primitive man" (*sauvages*) a two-footed animal, walking on its hands too if occasion calls, isolated, wandering in the forests, pairing at hazard, forgetting the woman with which he has mated, knowing neither her offspring nor his parents, living like a beast, only without the instinct and the resources of the beasts. You will find it in books that this state is the true estate of man, and that we have merely degenerated pitiably since we left it. But I do not think that this solitary life ascribed to our forefathers is in human nature at all. If I am not mistaken, we are in the first rank of the gregarious animals, much as bees, wasps, and the like. If you come across a strayed bee, ought you to infer that this bee is in the state of mere nature, and that those which work in association in the hive have degenerated? All men do live in Society: can you infer from that, that there was a time when they did not?' 'Man in general has always been what he is. That does not

[1] Chamisso, *Works*, i. 119.

mean that he has always had fine cities and so on: but he has always had the same instinct which leads him to feel affection for himself, for the companion of his toils, for his children, and so forth. That is what never changes, from one end of the world to the other. As the basis of society is always in existence, there always *is* some society. We were not made to live after the manner of bears'—a clear hit at the favourite simile of Montesquieu. 'It is therefore demonstrated that Nature alone inspires us with the useful conceptions which precede all our thoughts. In morals it is the same. We all have two instincts which are the basis of society, pity and justice.'[1]

From this fundamental uniformity of the human mind, which Voltaire assumes and defends, it follows that certain fundamental ideas recur everywhere, under suitable circumstances, more especially such religious dogmas as the conception of the immortality of the soul. In this conception it will be seen that Voltaire at the same time reverts almost completely to the anthropological standpoint of Aristotle, and anticipates by a century the philosophic position of Bastian. But it is also clear that Voltaire's mode of arriving at the Natural State of Man does not differ in its method from that of his predecessors. Both alike discover it by the process of subtracting from human nature, as we know it, all that can be traced to the operation of any positive prescription or observance. What each side finds lying behind this customary stratum of human nature, whether sheer passivity, or positive qualities of a selfish tendency, or otherwise, depends, as before, partly on the prejudices of the observer, but mainly on the current phase of emphasis on this or that section of what was known.

Christopher Meiners.

The new attitude towards Rousseau is well illustrated by the criticism of Christopher Meiners, whose 'Historical Comparison of the Customs and Constitutions, the Laws and Industries, the Trade and Religion, the Sciences and Educational Institutions of the Middle Ages' was published at Hanover in 1793. 'Experience, history, and sound reason,' he says, 'are mishandled (by Rousseau) with unprecedented audacity. On all sides false or distorted facts are treated as fundamental, and the best known and best attested observations are misinterpreted or left on one side.'[2] 'Among the poets of enlightened peoples there is hardly to be found any fiction so utterly in conflict with experience and history as Rousseau's picture of the State of Nature, and of Natural Man.' But Meiners' criticism is directed wholly against Rousseau's ignorance of anthropological fact, and most particularly of facts about 'modern savages'; not against the principles of his method. For, as Meiners himself contends, 'the most important conditions in which considerable sections of the human race have been or are now to be found, are the conditions of savagery and barbarism, of incipient, or half-completed, or entire enlightenment.' 'Human history devotes its particular attention to the savages and barbarians of all parts of the world, who have never produced the smallest perceptible change in the fortunes of humanity as a whole; because often a single small horde of savages and barbarians can make greater contributions to the knowledge of human nature than the most magnificent peoples who ever conquered and devastated a continent.' And Meiners goes on to hit also Montesquieu for his failure to appreciate the contribution of savages to political philosophy. Here we have clearly the beginnings of the modern comparative method, with its search for uncontaminated survivals of primitive, though not strictly 'pre-social' states.

Herder.

But it is mainly to Herder that the expression of the new movement is due; and it is his 'Thoughts on the History of Mankind'[3] that makes the first systematic

[1] Voltaire, *Œuvres*, xi. 19, 21; see also Rousseau's reply to this position, *Discours sur l'origine et les fondemens de l'inégalité parmi les hommes*, p. 170.

[2] Vol. i. pp. 7, 16, 18.

[3] Herder, *Ideen zur Geschichte der Menschheit.*

attempt to solve the problem of the development of man and his culture, and to create, in the modern sense, a Science of Man.

'Already in comparatively early years,' he says, 'when the field of knowledge lay before me in all that morning glory from which life's midday sun detracts so much, the idea often besets me, since everything in the world has its philosophy and science, ought not human history, which after all lies nearest to ourselves, to have in a general sense its philosophy and science also?' He argues, thereupon, that we must discard speculation and follow experience simply. 'When, therefore, we set about philosophising upon the history of our species, let us forswear, as far as possible, all narrow forms of thought which are derived from the culture of a single region, or even of a single school. It is not what man is among ourselves nor what he ought to be in the conception of any dreamer whatever'—this is clearly aimed at Rousseau—'but what he is on the earth in general, and at the same time in every single region in particular; or rather, what it is to which the rich multiplicity of accidents in the hands of Nature has had the power to train him. This is what we are to regard as the purpose of Nature for him.'

Herder, that is, conceives it as possible, at the same time to determine inductively what Man is in himself, and to determine by simple description what he actually is (or rather what *men* actually *are*) under the various different conditions in which we find him. But he insists on the distinction between these two modes of regarding Man, or Men; and rightly, for it is the confusion between the description of this or that kind of uncivilised Man—Iroquois, Hottentot, or South Sea Islander—and the guess that uncivilised Man everywhere *must* have such and such qualities or defects of qualities, which had in fact produced all the discrepancies between the previous theories of a Pre-Social state.

Writing when he did, Herder of course was but little more capable than his predecessors of delineating human nature in detail on inductive lines. His merit lies in the clearness with which he gripped and stated the conditions of the problem; in an advance of method, which came just in time to guide the theoretical treatment of a vast mass of new data. At the same time he did accomplish a good deal, even as regards the filling in of the picture. In particular he marks the turn of the tide from the philosophy of the Pre-Social State towards the old Aristotelian conception of Man as a social animal. Both Hobbes and Locke, though not I think anywhere named, come in for effective criticism. 'There have been philosophers,' he says, 'who on account of this instinct of self-preservation have classified our species among the Carnivora, and made out its natural state to be a state of war. Of course when Man plucks the fruit of a tree he is a robber; when he kills an animal he is a murderer; and when—with a footstep, with a breath, perhaps—he takes the life of myriads of invisible creatures, he is the most brutal oppressor on earth . . . But put Man among his brethren, and ask the question, Is he naturally a beast of prey to his own kind, is he an "unsocial" being? In his physical shape he is clearly not the former, by his birth still less the latter.' Herder is thus returning afresh to the Aristotelian conception of the parental bond as the complement and remedy of the long helpless infancy. Herder's ideal Man has, in fact, a Humanity which is in itself an end, an ideal, not a pre-social attribute, and just for this reason Humanity exists potentially in all members of the species, however small their progress towards realising it, or however eccentric the results of their social activity. 'Look at the godlike laws and regulations of Humanity, which emerge, if only in the merest traces, among the most savage peoples. Can they really have been invented by the exercise of reason only after the lapse of thousands of years? Can they really owe their origin to this changeful sketch, this man-made abstraction? I cannot believe it, even from the standpoint of history. If men had been distributed like animals on the earth's surface, to invent for themselves the inner form of Humanity, we should still find mere human stocks, without language, without reason, without religion or morals; for as Man was created such is he still upon the earth.'

The Patriarchal Theory.

All these theories of a Social Contract as the starting-point of human societies presupposed, as we have seen, that mankind had actually passed

hrough a Pre-Social State; and the proof which had been offered of this supposition, though partly theoretical and *a priori*, had partly also been inductive and based on experience. Further, the experience of 'primitive Man' which was actually open to the philosophers of the seventeenth and early eighteenth centuries had been, in fact, such as to force the conclusion not merely that a Pre-Social State had once existed, but that some barbarous peoples had not yet emerged from it. It was a sad error of observation, as we now know, which led to that conclusion; but given the travellers' tales, in the form in which we can read them in the 'Cosmographies' and 'Voyages' of the time, I do not see how that conclusion could have been avoided without culpable neglect of such evidence as there was. If blame is to be assigned in this phase of inquiry at all, it is to be assigned to the travellers and traders, for making such poor use of their eyes and ears. All, however, that I am concerned to establish at present is this, that one of the most important and far-reaching speculations of modern political philosophy, the speculation as to a Pre-Social Condition of Mankind, and a Social Contract which ended it and brought in Society and the State, arose directly and inevitably from the new information as to what primitive man *was* and *did*, when he was studied in the seventeenth century at Tombutum, or Saldanha Bay, or the 'backwoods of America,' or the 'bank of the Orinoco River.'

But the Social Contract Theory has long since passed out of vogue. Its political consequences are with us to-day, like the political consequences of the belief in the Divine Right of Kings; but the theories themselves are dead, and likely to remain so. Plato and Aristotle, with their belief in Man as a Naturally Social Animal, have come by their own again, for most of us, if not for all; and the search for an ideal State, which shall realise and fulfil Man's social instincts, is again in full cry.

What part, if any, has the direct study of barbarous people played at this fresh turn of the wheel? Let us look once again at the state of geographical knowledge, and more particularly, as before, at the regions in which by transitory chance of circumstances, there was most to be learned at the moment. First, the British occupation of India was the occasion, on the one hand, of the discovery of Sanskrit, the creation of this science of comparative philology, and the demonstration of a new link of cultural affinity over the whole realm of Aryan speech. The same political event led no less directly to the discovery of the patriarchal structure of Hindoo society, and so through the comparative study of Indian, Roman, and ancient Celtic and Teutonic law to an inductive verification of Aristotle's doctrine of the 'naturalness' of patriarchal society. This doctrine dominated political science for nearly fifty years. 'The effect of the evidence derived from comparative jurisprudence,' Sir Henry Maine could write in 1861,[1] 'is to establish that view of the primæval conditions of the human race which is known as the Patriarchal Theory. There is no doubt, of course, that this theory was originally based on the Scriptural theory of the Hebrew patriarchs in Lower Asia. . . . It is to be noted, however, that the legal evidence comes nearly exclusively from the institutions of societies belonging to the Indo-European stock, the Romans, Hindoos, and Sclavonians supplying the greater part of it; and indeed the difficulty, at the present stage of the inquiry, is to know where to stop; to say of what races of men it is *not* allowable to lay down that the society in which they are united was originally organised on the patriarchal model.' And he refers explicitly to the former controversy between Filmer and Locke, to point out how the tables had now been turned upon the latter.

Thus in the half-century which intervenes between Herder and Maine the political philosophy of Europe seemed to have turned almost wholly from exploration to introspection; from the Pacific to early Rome and the German forests; and from the study of survivals in the modern practice of savages, to that of primæval usages betrayed by the speech and customs of the civilised world. It was Aristotle over again, with his appeal to custom, ancestral belief, and canonical literature, following hard upon the heels of the visionary revolutionary Plato. Maine's own words, indeed, about Rousseau[2] would be applicable almost without change to the course of Greek thought in the fourth century B.C. 'We

[1] Maine, *Ancient Law*, pp. 122–3. [2] *Ibid.* pp. 86–9.

have never seen in our own generation,' he says, 'indeed the world has not seen more than once or twice in all the course of history, a literature which has exercised such prodigious influence over the minds of men, over every cast and shade of intellect, as that which emanated from Rousseau between 1749 and 1762. It was the first attempt to re-erect the edifice of human belief after the purely iconoclastic efforts commenced by Bayle, and in part by our own Locke, and consummated by Voltaire; and besides the superiority which every constructive effort will always enjoy over one that is merely destructive, it possessed the immense advantage of appearing amid an all but universal scepticism as to the soundness of all foregone knowledge in matters speculative. . . . The great difference between the views is that one bitterly and broadly condemns the present for its unlikeness to the ideal past, while the other, assuming the present to be as necessary as the past, does not affect to disregard or censure it.'

I have devoted some space to these first steps of Linguistic Palæontology and Comparative Jurisprudence because the method of inquiry which they announced promised at first sight to make good a very serious defect in the instruments of anthropological research. Human history, outside of Europe and of one or two great Oriental States like China, hardly went back beyond living memory; even Mexico had no chronicles beyond the first few hundred years, and the records of old-world States like China, which at first sight offered something, turned out on examination to have least to give. They had lived long, it is true, but their lives had been 'childlike and bland,' devoid of change, and almost empty of experience. Consequently there was no proof that the 'wild men' of the world's margins and byways were really primitive at all. The Churches held them children of wrath, degenerate offspring of Cain; the learned fell back upon pre-Adamite fictions to palliate, rather than to explain, their invincible ignorance of Europe and its ways. Here, however, in the new light thrown by the history of speech, there seemed to be a prospect of deep insight into the history of human societies. Disillusionment came in due course when doctors disagreed; but illusion need never have taken the form it did, had either the philologists or the philosophers realised that all the really valuable work was being done within the limits of a single highly special group of tongues; that the very circumstance that this group of tongues had spread so widely, pointed to some strong impulse driving the men who spoke them into far-reaching migrations; that one of the few points upon which linguistic palæontologists were really unanimous was that both the Indo-European and the Semitic peoples, in their primitive condition, were purely pastoral; and that this pastoral habit was itself an almost coercive cause for their uniformly patriarchal organisation. The last point, however, belongs so completely to another phase of our story that it is almost an anachronism to introduce it here. It serves however to indicate, once again, if that be necessary, how completely the philosopher, and even the man of science, is at the mercy of events in the ordering of his search after knowledge. It is, indeed, almost true to say that if the primitive Aryan had not had the good fortune not merely to live on a grass-land, but also to find domesticable quadrupeds there, there could no more have been a science of comparative philology in modern Europe, than there could be among the natives of your own Great Plains or of the Pacific Coast: for in no other event would there have been any such 'family of languages' to compare.

In the absence of warning thoughts like these, however, the comparative philology and the comparative law of the patriarchal peoples of the North-West Quadrant and of India went gaily on. What Maine had done for India, Maine himself, with Solm and von Maurer, in Germany; Le Play, de Laveleye, and d'Arbois de Joubainville in France; W. F. Skene in far-off Scotland; Whitley Stokes and others in Ireland; Rhys in Wales; and Mackenzie Wallace and Kovalevsky in Russia, had done for the early institutions of their respective countries: all emphasising alike the wide prevalence of the same common type of social structure, based upon the same central institution, the Patriarchal Family, with the *Patria Potestas* of its eldest male member as its overpowering bond of union; and Maine's own words do not the least exaggerate the beliefs and expectations which were evoked by this new aspect of the Study of Man.

The Matriarchate in Southern India, Africa, and North America.

The Patriarchal Theory lasted barely fifty years. It had owed its revival, as we have seen, to two fresh branches of research, comparative jurisprudence and comparative philology, both stimulated directly by the results of European administration in Northern India. It owed its decline to the results of similar inquiries in other parts of the world, stimulated no less directly by other phases of the great colonising movement, which marks, above all other things, the century from 1760 to 1860. Here again a small number of examples stand out as the crucial instances. British administration in India had, of course, been extended over the non-Aryan south, as well as over the north; and in Travancore, and other parts of the Madras Presidency, British commissioners found themselves confronted with types of society which showed the profoundest disregard of the Patriarchal Theory. Like the Lycians of Herodotus, these perverse people 'called themselves after their mothers' names': they honoured their mother and neglected their father, in society and government, as well as in their homes; their administration, their law, and their whole mode of life rested on the assumption that it was the women, not the men, in whom reposed the continuity of the family and the authority to govern the State. Here was a *parecbasis*, a 'perverted type' of society, worthy of Aristotle himself. It is a type which, as a matter of fact, is widely distributed in Southern and South-eastern Asia, and had been repeatedly described by travellers from the days of Tavernier (in Borneo) and Laval (in the Maldive Islands), if not earlier still. It existed also in the New World, and Lafitau had already compared the Iroquois with the ancient Lycians. But it was Buchanan's account of the Nairs of the Malabar Coast, published in 1807, which came at the 'psychological moment,' and first attracted serious attention. At the other extremity of India, also, analogous customs were being recorded, about the same time, by Samuel Turner in Tibet, which might have given pause at the outset to the speculators who hoped to base general conclusions on anything so special and peculiar as the customs of Aryan India.

Similar evidence came pouring in during the generation which followed; partly, it is true, as the result of systematic search among older travellers, but mainly through the intense exploitation of large parts of the world by European traders and colonists. Conspicuous instances are the Negro societies of Western and Equatorial Africa, first popularised by the republication of William Bosman's 'Guinea' (1700), in Pinkerton's 'General Collection of Voyages and Travels' (London, 1808, &c.), and by Proyart's 'Histoire de Loango' (1776), which also reached the English public in the same invaluable collection. But it was from the south that the new African material came most copiously, in proportion as the activity of explorers, missionaries, and colonists was greater. Thunberg's account of the Bechuanas [1] takes the lead here; but for English thought the principal authorities are, of course, John Mackenzie [2] and David Livingstone.[3]

It was not to be expected that America, which had made such remarkable contributions to the study of Man in the seventeenth and eighteenth centuries, should fall behind in the nineteenth, when its vast resources of mankind, as of Nature's gifts, were being realised at last. From Hunter,[4] Gallatin,[5] and Schoolcraft,[6] in the twenties, to Lewis Morgan [7] in 1865, there was hardly a traveller 'out West' who did not bring back some fresh example of society destructive of the Patriarchal Theory.

As often happens in such cases, more than one survey of the evidence was in

[1] Pinkerton, vol. xvi.

[2] John Mackenzie, *Ten Years North of the Orange River* (1859–69). Edinburgh, 1871.

[3] David Livingstone, *Narrative of an Expedition to the Zambesi and its Tributaries* (1858–64). London, 1865.

[4] Hunter, *Manners and Customs of several Indian Tribes located West of the Mississippi.* Philadelphia, 1823.

[5] Gallatin, *Archæologia Americana.* Philadelphia (from 1820 onwards).

[6] Schoolcraft, *Travels in the Central Portions of the Mississippi Valley* (New York, (1825); *Notes on the Iroquois* (1846).

[7] Lewis H. Morgan, *Proc. Am. Acad. Arts and Sciences*, vii. 1865–8.

progress simultaneously. Bachofen was the first to publish,[1] and it is curious that his great book on 'Mother-right' appeared in the very same year as Maine's 'Ancient Law.' Lubbock's 'Prehistoric Times,' in the next year, represents the same movement of thought in England in a popular shape, but almost independently. In America, Lewis Morgan, whom I have noted already as an able interpreter of Iroquois custom, followed up his detailed studies of Redskin law by a Smithsonian monograph in 1871 on 'Systems of Consanguinity and Affinity of the Human Family,' and, in 1877, by his book on 'Ancient Society.' Meanwhile Post had published his great work on the 'Evolution of Marriage'[2] in 1875, and J. F. McLennan his first 'Studies in Ancient History' in 1876. It was the generation of Darwin and of the great philologists, as we have seen, and 'survivals' were in the air: Dargan[3] pointed out traces of the Matriarchate in the law and custom of Germany, and Wilken[4] in those of early Arabia. The period of exploration, if I may so term it, closed on this aspect of the subject with Westermarck's 'History of Human Marriage,' which was published in London in 1891.

Australian Evidence: Totemism and Classificatory Kinship.

I have now mentioned India, South Africa, and North America, three principal fields of English-speaking enterprise during the nineteenth century, and have indicated the contribution of each to modern anthropology in its bearing on political science. Only Australia remains; and, though Australia's task has been shared more particularly with North America, I shall be doing no injustice to Lewis Morgan or to McLennan if I couple with their names those of Fison and Howitt,[5] as the discoverers of classical instances of societies which observe neither paternal nor maternal obligations of kinship as we understand them, but have adopted those purely artificial systems of relationships which in moments of elation we explain as 'Totemic,' or, in despair, describe as 'classificatory.'

Hermann Post: Comparative Jurisprudence.

Our retrospect, therefore, of the last fifty years shows clearly once again how intimately European colonisation and anthropological discoveries have gone hand in hand: first to establish a 'Matriarchal Theory' of society as a rival of the Patriarchal; and then to confront both views alike with the practices and with the theories of 'Totemism.'

From the point of view of political science, all this mass of inquiries finds applications already in more departments than one; though it is probably still too early to appraise its influence adequately. The new Montesquieu has not yet arisen to interpret to us the 'Spirit of the Laws.' Most directly, perhaps, we can trace such influence in the 'Comparative Jurisprudence' of Hermann Post, whose first work on the 'Evolution of Marriage' appeared, as we have seen, in 1875. Post's general attitude is best seen in his 'Introduction to the Study of Ethnological Jurisprudence,' which was published in 1886, and in his 'African Jurisprudence' of 1887.[6] As the result of a survey of social organisations, considered as machinery in motion, Post points out very justly that it is useless to attempt to explain social phenomena on the basis of

[1] Bachofen, *Das Mutter-recht.* Stuttgart, 1861.

[2] Hermann Post, *Die Geschlechtsgenossenschaft der Urzeit und die Entstehung der Ehe.* Oldenburg, 1875.

[3] Dargan, *Mutter-recht und Raub-ehe und ihre Reste im Germanischen Recht und Leben.* Breslau, 1883.

[4] Wilken, *Das Matriarchat bei den alten Arabern.* Leipzig, 1884.

[5] Fison and Howitt, *Kamilaroi and Kurnai.* Melbourne and Sydney, 1880.

[6] Hermann Post, *Einleitung in das Studium der ethnologischen Jurisprudenz* (Oldenburg 1886); *Afrikanische Jurisprudenz* (1887). His position is, however, already clear in his first synthetic work, *Der Ursprung des Rechts*, 1876, as well as in his earlier book on Marriage. For a good summary of Post's views see Th. Achelis, *Die Entwickelung der modernen Ethnologie* (Berlin, 1889), p. 113–128, and the same writer's *Moderne Ethnologie* (1896).

the psychological activities of individuals, as is too commonly assumed, because all individuals whose conduct we can possibly observe have themselves been educated in some society or other, and presume in all their social acts the assumptions on which that society itself proceeds. 'I take the legal customs of all peoples of the earth,' so he wrote in 1884,[1] 'the residual outcome of the living legal consciousness of humanity, for the starting-point of my inquiry into the science of law; and then, on this basis, I propound the question, What is law? If by this road I arrive eventually at an abstract conception of law, or at an idea of law, then the whole fabric so created consists, from base to summit, of flesh and blood.' It is the same method, of course, which had already yielded such remarkable results to Montesquieu, and even to Locke. The point of view is no longer that of a Maine or a McLennan, students of patriarchal or of matriarchal institutions by themselves. It is that of a spectator of human society as a whole; and such a point of view only became possible at all when it was already certain that no great section of humanity remained altogether unexplored, however fragmentary our knowledge might still be of much that we ought to have recorded. And its immediate outcome has been to throw into the strongest possible relief the dependence of the form and, still more, of the actual content of all human societies on something which is not in the human mind at all, but is the infinite variety of that external Nature which Society exists to fend off from Man, and also to let Man dominate if he can.

This was, of course, already the standpoint of Comte, with his emphasis on the *monde ambiant*. But Comte, the citizen of a State which except in Canada had failed to colonise, and therefore had little direct contact with non-European types of society, confined himself far too exclusively to European data. His strength is precisely where the science of France was so magnificently strong in his day, in the domain of pure physics; it is his analogies between politics and physics which are so illuminating in his work, as in that of his English compeer, Herbert Spencer;[2] and it is the weakness of both in the direction of anthropology which mainly accounts for the shortness of their respective vogues.

Friedrich Ratzel: Anthropo-geography.

At the point which we have now reached in this rapid survey of our science, it was obviously to Geography—the systematic study of those external forces of Nature as an ordered whole—that Anthropology stretched out its hands; and it did not ask in vain. But while English geography had remained exploratory, descriptive, and (like English geology) *historical* in its outlook, the new German science of *Erdkunde*—'earth-knowledge' in the widest sense of the word—had already come into being, on the basis of the labours of Ritter and the two Humboldts, and under the guidance of such men as Wagner, Richthofen, and Bastian; the last named also an anthropologist of the first rank. It was thus to a distinguished pupil of Wagner, Friedrich Ratzel, that anthropology owed, more than to any other man, the next forward step on these lines. In Ratzel's mind, History and Geography went hand in hand as the precursors of a scientific Anthropology.[3] History to define *when*, and in what order, Man makes his conquests over Nature; Geography to show *where*, and within what limits, Nature presents a conquerable field for Man. Much of this, of course, was already implicit in the teaching of Adolf Bastian, whose monumental volumes on 'Man in History' had appeared at Leipzig as early as 1860; his 'Contributions to Comparative Psychology' in 1868; and his 'Legal Relations among the Different Peoples of the Earth' in 1872[4]—three years before Post's first essay. But Bastian, inaccessible for years together in Tibet or Polynesia, was rather an inspiration to a few intimate colleagues than a great propagandist; and besides, it was not till the appearance

[1] Post, *Die Grundlagen des Rechts* (1884).

[2] Compare Quetelet's *Essai de Physique Sociale* (1841), as a symptom of the trend of French thought at this stage.

[3] Ratzel, *Anthropo-geographie.* Leipzig, vol. i. 1882; ii. 1891.

[4] Bastian, *Der Mensch in der Geschichte* (Leipzig, 1860); *Beiträge zur vergleichenden Psychologie* (Berlin, 1868); *Rechtsverhältnisse bei verschiedenen Völkern der Erde* (Berlin, 1872).

of his 'Doctrine of the Geographical Provinces' in 1886[1] that he touched on this precise ground, and by that time Ratzel's 'History of Man' had already been out for a year.[2]

Epilogue.

These examples, I think, are sufficient to show how intimately the growth of political philosophy has interlocked at every stage with that of anthropological science. Each fresh start on the never-ending quest of *Man as he ought to be* has been the response of theory to fresh facts about *Man as he is.* And, meanwhile, the dreams and speculations of one thinker after another—even dreams and speculations which have moved nations and precipitated revolutions—have ceased to command men's reason when they ceased to accord with their knowledge.

And we have seen more than this. We have seen the very questions which philosophers have asked, the very problems which perplexed them, no less than the solutions which they proposed, melt away and vanish, *as problems,* when the perspective of anthropology shifted and the standpoint of observation advanced. This is no new experience; nor is it peculiar either to anthropology among the natural sciences, or to political science among the aspects of the Study of Man. It is the common law of the mind's growth, which all science manifests, and all philosophy.

And now I would make one more attempt to put on parallel lines the course of anthropology and of political thinking. It is not so very long ago that a great British administrator, returning from one of the gravest trials of statesmanship which our generation has seen, to meet old colleagues and class-mates at a college festival, gave it to us as the need he had most felt, in the pauses of his administration, that there did not exist at present any adequate formulation of the great outstanding features of our knowledge (as distinct from our creeds) about human societies and their mode of growth, and he commended it to the new generation of scholarship, as its highest and most necessary task, to face once more the question: What are the forces, as far as we can know them now, which, as Aristotle would have put it, 'maintain or destroy States'?

But if a young student of political science were to set himself to this life work, where could he turn for his facts? What proportion of the knowable things about the human societies with which travellers' tales and the atlases acquaint him could he possibly bring into his survey, without a lifetime of personal research in every quarter of our planet?

I have in mind one such student setting out this coming session to investigate, on the lines of modern anthropology, the nature of *Authority* and the circumstances of its rise among primitive men; and the difficulty at the outset is precisely as I have described. In the case of the 'black fellows' of Australia such a student depends upon the works of some four or five men, representing (at a favourable estimate) one-twentieth even of the known tribes of the accessible parts of that continent. For British South Africa he would be hardly better served; for British North America, outside the ground covered in British Columbia by Boas and Hill-Tout, he would have almost the field to himself; and the prospect would seem to him the drearier and the more hopeless when he compared it with things on the other side of the forty-ninth parallel.

Now, our neighbours south of that line have the reputation of being practical men; in other departments of knowledge they are believed to know well 'what pays.' And I am forced to believe that it is because they know that it *pays* to know all that can still be known about the forms of human society which are protected and supervised from Washington, that they have gone so far as they have towards rescuing that knowledge from extinction while still there is time. The Bureau of Ethnology of the United States of America is the most systematic, the most copious, and, I think, taking it all in all, the most scientific of the public agencies for the study of any group of men, *as men.* The only other which can be compared with it is the ethnographical section of the last census of India, and that

[1] Bastian, *Zur Lehre von den geographischen Provinzen.* Berlin, 1886.

[2] Ratzel, *Völkerkunde* (Leipzig, 1885). His *method* is best studied in the first volume of his *Anthropo-geographie* (Leipzig, 1882).

was an effort to meet, against time, an emergency long predicted, but only suddenly foreseen by the men who were responsible for giving the order. Thus, humanly speaking, it is now not improbable that in one great newly-settled area of the world every tribe of natives, which now continues to inhabit it, may at least be explored, and in some cases really surveyed, before it has time to disappear. But observe, this only applies to the tribes which now continue to exist; and what a miserable fraction they are of what has already perished irrevocably! It is no use crying over spilt milk, as I said to begin with; the only sane course is to be doubly careful of whatever remains in the jug.

An Ethnological Survey for Canada.

And now I conclude with a piece of recent history, which will point its own moral. When the British Association met first outside the British Isles, it celebrated its meeting at Montreal by instituting, for the first time, a section for Anthropology; and it placed in the chair of that section one of the principal founders of modern scientific anthropology, Dr. Edward Burnett Tylor, then recently installed at Oxford, and still the revered Professor of our science there. Through his influence mainly, but with the active goodwill of the leading names in other sciences in Canada, a research committee was formed to investigate the north-west tribes of the Dominion; and for eleven consecutive years expeditions wholly or partly maintained by this Association were sent to several districts of British Columbia. These expeditions cost the Association about £1,200 in all. I am glad to think that the chief representative of this Committee's work, Dr. Franz Boas, has long since realised, in his great contributions to knowledge, the high hopes which his early reports inspired.

When the Association met the second time on Canadian soil, at Toronto, the occasion seemed opportune for a fresh step. Dr. Boas had already undertaken work on a larger scale and under other auspices. But it was thought likely that if a fresh Committee of the Association were appointed, with wider terms of reference and further grants, it would be possible to select and to train a small staff of Canadian observers, and by their means to produce such a series of preliminary reports on typical problems of Canadian anthropology as would satisfy the Dominion Government that the need for a thorough systematic survey was a real one, and that such a survey would be practicable with the means and the men which Canada itself could supply. Among the leading members of this Ethnographic Survey Committee I need only mention three—the late Dr. George Dawson, Mr. David Boyle, and Mr. Benjamin Sulte, each eminent already in his own line of study, and all convinced of the great scientific value of what was proposed. The first year's enterprise opened well; workers were found in several districts of Canada; the Association sent out scientific instruments, and formed in London a strong consultative committee to keep the Canadian field-workers in touch with European students of the subject. But the premature death of George Dawson in 1901 broke the mainspring of the machine; the field-workers fell out of touch with one another and with the subject; the instruments were scattered, and in 1904 the Ethnographic Survey Committee was not recommended for renewal.

I need not say how great a disappointment this failure has been to those of us who believe that in this department of knowledge Canada has great contributions to make, and who know—as this Meeting too knows perfectly well—that if this contribution to knowledge is not made within the next ten years, it can never be made at all. I am not speaking merely of the urgency of exact study of the Indian peoples. This indeed is obvious and urgent enough; and the magnificent results of organised effort in the United States are there to show how much you too can still rescue, if you will. But at the moment I appeal rather for the systematic study of your own European immigrants, that stream of almost all known varieties of white men with which you are drenching yearly fresh regions of the earth's surface, which if they have had experience of human settlements at all, have known man only as a predatory migratory animal, more restless than the bison, more feckless and destructive than the wolf. Of your immigrants' dealings with wild nature you are indeed keeping rough,

undesigned record in the documents of your Land Surveys, and in the statistics of the spread of agriculture over what once was forest or prairie; and in time to come, *something*—though not, I fear, much—will exist to show what good (and as likely as not, also, what irremediable harm) this age of colonisation has done to the region as a whole. But what you do not keep record of is Nature's dealings with your immigrants; you do not *know*—and as long as you omit to *observe* you are condemned not to know—the answer to the simple, all-important question, *What kinds of men do best in Canada? What kind of men is Canada making out of the raw material which Europe is feeding into God's Mills on this side?*

Over in England, we are only too well aware how poor a lead we have given you. We, too, for a century now, have been feeding into other great winnowing chambers the raw crop of our villagers. We have created (to change the metaphor) in our vast towns great vats of fermenting humanity, under conditions of life which at the best are unprecedented, and at their worst almost unimaginable. That is *our* great experiment in modern English anthropology—*What happens to Englishmen in City-slums?* and we shall hear, before this Meeting ends, something of the methods by which we are attempting now to watch and record the outcome of that experiment in the making of the English of to-morrow. We are beginning to know, in the first place, what types of human animal can tolerate and survive the stern conditions of modern urban life. We are learning, still more slowly, what modes of life, what modified structure of the family, of the daily round, of society at large, can offer the adjustment to new needs of life which human nature demands under this new, almost unbearable strain. We are seeing, more clear in the mass, even if hopelessly involved in detail, the same process of selection going on in the mental furniture of the individuals themselves; new views of life, new beliefs, new motives and modes of action; new, if only in the sense that they presuppose the destruction of the old.

That is our problem in human society at home. And yours, though it has a brighter side, is in its essentials the same. Geographers can tell you something already of the physical 'control' which is the setting to all possible societies on Canadian soil. Scientific study of the vanishing remnants of the Redskin tribes may show you a little of the effects of this control, long continued, upon nations whom old Heylin held to be 'doubtless the offspring of the Tartars.' Sympathetic observation and friendly intercourse may still fill some blanks in our knowledge of their social state; how hunting or fishing—or, in rare cases, agriculture—forms and reforms men's manners and their institutions when it is the dominant interest in their lives. But what climate and economic habit have done in the past with the Redskins, the same climate and other economic habits are as surely doing with ourselves. In the struggle with Nature, as in the struggle with other men, it is the weakest who go to the wall; it is the fittest who survive. And it is our business to *know*, and to record for those who come after us, what manner of men we were, when we came; whence we were drawn, and how we are distributed in this new land. An Imperial Bureau of Ethnology, which shall take for its study all citizens of our State, as such, is a dream which has filled great minds in the past and may some day find realisation. A Canadian Bureau is at the same time a nearer object, and a scheme of more practicable size. In the course of this Meeting, information and proposals for such a Bureau of Ethnology are to be laid before this section by more competent authorities than I. My task has only been to show, in a preliminary way, what our science has done in the past, to stimulate political philosophy, and to determine its course and the order of its discoveries.

'Some men are borne,' said Edward Grimstone just three centuries ago, 'so farre in love with themselves, as they esteeme nothing else, and think that whatsoever fortune hath set without the compasse of their power and government should also be banished from their knowledge. Some others, a little more carefull; who finding themselves engaged by their birth, or abroad, to some one place, strive to understand how matters pass there, and remaine so tied to the consideration of their owne Commonweale, as they affect nothing else, carrying themselves as parties of that imperfect bodie, whereas in their curiositie they should behave themselves as members of this world.' It is as 'members of this world,' I hope, that we meet together to-day.

The following Reports and Paper were then read:—

1. *Report on the Investigation of the Lake Villages in the Neighbourhood of Glastonbury.*—See Reports, p. 270.

2. *Report on Excavations on Roman Sites in Britain.* See Reports, p. 271.

3. *Report on the Age of Stone Circles.*—See Reports, p. 271.

4. *Report on the Preparation of a New Edition of 'Notes and Queries in Anthropology.'*—See Reports, p. 285.

5. *Report of the Anthropological Photographs Committee.* See Reports, p. 285.

6. *Report of the Committee to Organise Anthropometric Investigation in the British Isles.*—See Reports, p. 286.

7. *Report on Archæological Investigations in British East Africa.* See Reports, p. 286.

8. *Interim Report on the Establishment of a System of Measuring Mental Characters.*

9. *Race-types in the Ancient Sculptures and Paintings of Mexico and Central America. By* Miss A. C. BRETON.

The different race-types in the ancient sculptures and paintings found in Mexico and Central America form an important anthropological study. An enormous mass of material, evidently of many periods, includes sculpture, archaic stone statuettes, the portrait statues and reliefs at Chichen Itza, the Palenque reliefs and the series of magnificent stelæ and lintels at Piedras Negras, Yaxchilan, Naranjo, Copan, Quirigua, etc.

In terra cotta or clay there are the hundreds of thousands of small portrait heads and figurines found at Teotihuacan, Otumba, the neighbourhood of Toluca, and other ancient sites. Larger clay figures have been found in quantities in tombs, as in the States of Jalisco and Oaxaca; these were made as offerings, instead of the sacrifice at a chief's burial of his wives and servants. Small jadeite heads and figures, also found in tombs, show strongly marked types. If there are few specimens in gold, it is because throughout the country the Spaniards ransacked the tombs for gold. In painting there are the picture manuscripts, the frescoes at Chichen Itza, Chacmultun, and Teotihuacan, and a number of vases with figures from Guatemala and British Honduras.

This material is now available for students in Mr. A. Maudslay's 'Biologia Centralis-Americana, Archæology,' Dr. E. Seler's collected works,

the publications of the Peabody Museum, and the reproductions of the Codices by the Duc de Loubat, also in the splendid collections of the Museum für Völkerkunde at Berlin, the Mexican Hall of the Natural History Museum at New York, and the Peabody Museum.

Among distinctive types are:—The chiefs in the reliefs at Xochicalco, who sit cross-legged; the little shaven clay heads at Teotihuacan; the tall, well-built priests, with protruding lower lip, of the Palenque reliefs; the fifteen caryatid statues in feather mantles, of the Upper Temple of the Tigers, at Chichen Itza, and the sixteen stern warriors carved at its doors, these last similar in type to some of the modern Indians of the villages near Tlaxcala.

There are portraits of the Mexican kings on the border of a picture-map which represents the western quarter of Tenochtitlan, and of the householders in that part of the city. Of female types there are the painted clay figures of Jalisco, with compressed heads. Some of them have short, broad figures, others are slender. Both types still survive. The queenly women in Codex Nuttall-Zouche, and the women-chiefs of the Guatamalan stelæ, belonged to a different caste to the obviously inferior women on those stelæ, fattened in preparation for sacrifice.

Herr T. Maler's most recent explorations on the borders of Guatamala have given magnificent results, in the finding of thirty-seven stelæ at Piedras Negras, and, at Yaxchilan, of twenty stelæ and forty-six sculptured lintels. The superb figures of warriors and priests indicate a race of men of tall, slender stature and oval face, with large aquiline nose, whilst the captives appear to be of a different race.

FRIDAY, AUGUST 27.

The following Reports and Papers were read:—

1. *Interim Report on Archæological and Ethnological Researches in Crete.*—See Reports, p. 287.

---

2. *Recent Hittite Research.*[1] By D. G. Hogarth, *M.A.*

---

3. *Researches in the Maltese Islands in Recent Years.* *By* T. Ashby, *M.A.*, *D.Litt.*, *and* T. E. Peet, *M.A.*

Excavations have been conducted by the Government of Malta on the Corradino Hill, in which the co-operation of the British School at Rome has been cordially welcomed, and its investigations assisted in every way; the supervision has been entrusted to the Director of the School and to Mr. T. E. Peet, Student of the School, assisted by the constant co-operation of Dr. T. Zammit, Curator of the Museum. The great megalithic buildings of Gigantia, Mnaidra, and Hağar-Kim, which Dr. Arthur Evans considers to have been buildings of a sepulchral character in which a cult of departed heroes gradually grew up, and other smaller prehistoric monuments of the islands, have been carefully described by Dr. Albert Mayr, though others have since become known, but excavation was needed in order that many essential facts might be ascertained. The investigation of the rock-cut hypogeum of Halsaflieni, the architectural features of which imitate in the most surprising way those of the sanctuaries above ground, has for the first

[1] To be published in the *Journal of the Royal Anthropological Institute.*

time produced an adequate series, available for study, of the prehistoric pottery of Malta; for from the excavations of Hağar-Kim, unfortunately, but little has been preserved. Dr. Zammit and Professor Tagliaferro will shortly publish adequate descriptions of the hypogeum and its contents. Of the three groups of megalithic buildings on the Corradino Hill, two had been already in great part excavated in the nineties, and the complete clearing of the upper one, which apparently was of a domestic character, was the first work undertaken in May. Its plan is extremely irregular, and much of it can hardly have been roofed unless in thatch or woodwork. A considerable quantity of pottery was found, very similar in character to that of Halsaflieni, and belonging, like it, to the late neolithic period. It has some affinities with pottery recently found at Terranova, the ancient Gela, in Sicily, but in many respects is unique. Many flints were found, but no traces of metal. A stone pillar was found in one portion of the building, some 2 feet 8 inches long and about 10 inches in diameter, which may have been an object of worship. The excavation of a second and smaller group, nearer the harbour, had been already completed by Dr. Zammit and Professor Tagliaferro; but a third, further to the south, on the summit of the ridge, had never been examined, and it, too, was thoroughly investigated. An even larger quantity of pottery of the same character was found, with flints and fragments of stone basins, etc. It approximates more in style to the larger megalithic buildings of the island, and has a façade with a more pronounced curve than at Hağar-Kim, constructed of very large blocks, but much ruined. The interior consists of several distinct groups of rooms (often apsidal) not intercommunicating. The construction is of rough masonry, with large slabs at the bottom and smaller blocks higher up; the walls begin to converge, even at the height (5 to 6 feet) to which they are preserved, as though to form a roof. Into one of the rooms a very curious trough has at a later period been inserted: it is cut in a block of the local hard stone, 8 feet 9 inches long and 3 feet 8 inches wide, and is divided by six transverse divisions into seven small compartments, which show much trace of wear. The object of it is not as yet apparent. Another more carefully constructed room, perhaps contemporary with the trough, has its walls partly of large slabs, partly of narrow pillar-like stones. The floors of these rooms are sometimes of cement, sometimes of slabs. Many bones of animals were found, but only one human skeleton, and that in disorder and at a comparatively high level. The use of standing slabs at the base of walls, with coursed masonry above, visible in these buildings, finds its parallel in the Giants' tombs at Sardinia, the prehistoric huts of Lampedusa, and in many other places.

---

4. *Report on Archæological and Ethnological Investigations in Sardinia.* See Reports, p. 291.

---

5. *The Influence of Geographical Factors on the Distribution of Racial Types in Africa. By* Dr. F. C. Shrubsall.

MONDAY, AUGUST 30.

Papers and Discussion relating to a proposed Ethnological Survey of Canada.

A.—The Aboriginal Peoples.

(i) *Retrospect of previous Work by the British Association and other Agencies. By* E. Sidney Hartland, *F.S.A.*

(ii) *Ethnological Problems of Canada.* *By* Dr. F. Boas.

After a brief enumeration of some of the gaps in our knowledge, the author pointed out that the general outlines of Canadian ethnology had become known through reconnaissances carried out largely under the auspices of the British Association for the Advancement of Science, and that the task of the future would be a systematic study of the ethnological problems of the country. He discussed these problems in their relation to the general ethnological problems of the American continent. While in the whole area, from the Argentine Republic northward to the Great Lakes, certain characteristic traits of civilisation are found which differentiate the civilisation of ancient American from those of other continents, distinct types of culture are found in the extreme north-west of the continent, including the whole area from California to the coast of Labrador, and in the extreme south-west in Brazil and Tierra del Fuego. This suggests that these marginal areas may possess a culture older than that of the middle part of the continent, and not opposed to the same historic influences. Among the Canadian tribes only the Iroquois and a few of the southern tribes, like the Blackfeet and Assiniboins, belong to the middle area of the continent. All the rest belong to the northern marginal area. The tribes east of Great Slave Lake and of the northern interior of Labrador may represent this civilisation in its present form. The problem becomes still more difficult owing to undoubted influences that have extended from Asia into America, and which reach Hudson Bay and the Great Plains. The unravelling of these historical conditions is perhaps the most important problem to be solved by a study of Canadian ethnology.

Ethnologists are not yet in accord in regard to the theory of the gradual development of civilisation. While some believe that similarities of culture occurring among diverse tribes, sometimes wide apart, are due to psychological similarities, others believe that gradual dissemination has played an important part. In Canada there are at least six distinct types of culture—that of the Eskimo, the North-West Coast, the Mackenzie Barrier and of the western plateaus, that of the Plains, that of the eastern woodlands, and that of the Iroquois. The study of the relations of these will help to clear up the fundamental anthropological problems, which are of great theoretical interest, and which have, also, a direct practical bearing upon our views relating to the history and future of our own civilisation.

(iii) *The Anthropological Work of the University of Pennsylvania.* *By* Dr. G. B. Gordon.

Dr. Gordon, in reviewing the researches into the history of man in the North American continent that have been carried on under the auspices of the Government and institutions of the United States, called attention to certain far-reaching changes that have been witnessed in the attitude of the educated classes, and especially of learned institutions, with reference to those studies that fall directly within the province of anthropology. These changes are destined to affect very profoundly those interrelated branches of learning which, like history and sociology, are more directly affected by the anthropological method. These tendencies are made manifest by the history of anthropological activities in those quarters which are most influential in shaping educational development and methods of research. The work of the Bureau of Ethnology has been a prominent factor in promoting that interest in the study of the native races which has been carried on with successful results by the universities and museums of the country. Nothing in the history of anthropology is more

significant than the present condition of archæological studies as contrasted with that which obtained a few years ago. Until recently the very name of American archæology was noxious because it was foreign to European civilisation. To-day the chief archæological interest lies in the prehistoric period, and with the realisation of the unity of all problems of human development comes a rapidly increasing interest in American archæology. Dr. Gordon then reviewed the work of the various universities and museums, and paid a tribute to the services rendered by private individuals, both in forming collections and in organising expeditions.

B.—Ethnographic Study of the White Settlers.
By Dr. F. C. SHRUBSALL.

TUESDAY, AUGUST 31.

The following Papers and Report were read:—

1. *On a recent Find of Copper Implements in Western Ontario.*
By Professor E. GUTHRIE PERRY.

The implements exhibited were found at Fort Frances, below the Alberton Falls. The find consisted of twenty-seven fish-hooks, three arrow- and six spear-heads. All were made of cold-hammered copper from the Lake Michigan or Lake Superior District.

---

2. *On the Ethnology of the Okanagan of British Columbia.*[1]
By C. HILL-TOUT.

This paper dealt with the habitat, language, culture, and beliefs of this people, who are the easternmost division of the Salish of British Columbia. A common language is spoken by the whole division, and its relation to contiguous divisions of the same stock was discussed. The material and social culture is also similar to that of the other divisions.

From the evidence of culture and language it seems clear that the rivers and bays of the North Pacific slope were not the home of the stock before its division into its present linguistic groupings, and the evidence of language points to a connection with Oceanic stocks.

---

3. *A Nubian Cemetery at Anibeh.* *By* Dr. D. RANDALL-MACIVER.

---

4. *Arms and Accoutrements of the Ancient Warriors at Chichen Itza.*
By Miss A. C. BRETON.

Chichen Itza, in Yucatan, is as yet the principal place in the region of Mexico and Central America where representatives of armed warriors are found. There was a remarkable development in the later history of the buildings there of painted sculptures and wall-paintings, mostly of battle scenes and gatherings of armed chiefs.

The stone walls of the ruined lower hall of the Temple of the Tigers

[1] To be published in full in the *Journal of the Royal Anthropological Institute.*

are covered with sculptured rows of chiefs, who carry a variety of weapons. Of the sixty-four personages left, half a dozen have ground or polished stone implements; others hold formidable harpoons (two of them double) or lances adorned with feathers; whilst the majority have from three to five spears and an atlatl (*i.e.*, throwing stick). These are of different shapes. One figure has armlets with projecting rounded stones. Some have kilts, sporrans, leggings, and sandals. Eleven personages have tail appendages. There are protective sleeves in a series of puffs, breastplates, helmets, and feather headdresses, necklaces of stone beads, masks, ear and nose ornaments in variety. Small round back-shields, always painted green and fastened on by a broad red belt, may have been of bronze attached to leather, as a bronze disc has been found. Round or oblong shields were carried by two thongs, one held in the left hand, the other slipped over the arm.

The two upper chambers of the same building have reliefs on the door jambs of sixteen warriors, life size. They carry a sort of boomerang in addition to spears and atlatls. In the outer chamber was a great stone table or altar, supported by fifteen caryatid figures. Upon its surface was a relief of a standing chief, holding out his atlatl over a kneeling enemy who offers a weapon. The walls of both chambers were covered with painted battle scenes, in which several hundred figures are still visible. They carry spears, atlatls, round or oblong shields, and a kind of boomerang which was used by the natives in Australia about eighty years ago. It was intended for striking rather than throwing. On one wall the method of attacking high places by means of long-notched tree-trunks as ladders and scaffold towers is shown.

The building at the north end of the great Ball Court is evidently very ancient, and its sculptured walls have chiefs with spears and atlatls. The temple on the great pyramid called the Castillo also has warriors on its doorposts and pillars, with boomerangs, spears, and atlatls, and so has a building in the great Square of Columns. In an upper chamber of the palace of the Monjes are paintings in which are men with spears and atlatls, and also spears with lighted grass attached thrown against high-roofed buildings. A survey of all that has so far been discovered at Chichen gives a vivid idea of primitive battle array.

---

5. *Ethnological Researches in Alaska. By Dr.* G. B. Gordon.

In 1907 the author made an expedition to the Koskokwin Valley of Alaska to investigate the natives of that region, who, owing to their remoteness, preserve in a marked degree their aboriginal characteristics.

In the Upper Valley of the Koskokwin Déné tribes were found; seven hundred miles down the river Eskimo culture began; and two hundred miles further Eskimo customs prevailed and the tendency of the Déné of this district to adopt Eskimo culture is strongly marked and shows that the Eskimo culture is the more aggressive and the more advanced. At the mouth of the Koskokwin the Eskimo communities have retained in full vigour their peculiar customs and mode of life, because that part of the Alaskan coast has not been invaded by trading vessels or whalers.

The general health and physical welfare of these communities were noticeably better than in those locations where the natives have been in continued contact with the white men. At the same time their mental and moral state is also decidedly better. All observations tended to show that the inhabitants of Alaska, both Déné and Eskimo, undergo physical and moral deterioration under the influence of civilisation.

---

6. *The Archæology of Ontario and Manitoba.* *By* Henry Montgomery, *M.A., Ph.D.*

The history of Ontario during the seventeenth century has been supplemented by the work of archæologists, and valuable collections are preserved in Toronto University, in the Normal School, and in Laval University. There were several occupations of the Province. Village sites have been discovered. Many objects of manufacture have been found in the soil or upon the surface of the ground, such as primitive flints, well-made arrow-points, bone skewers and knives, stone scrapers, wedges, gouges, hammer-stones and amulets, pottery pipes and broken vessels of pottery. Ossuaries occur in which many human skeletons were found; some of the crania have inca bones, high supra-orbital ridges and low foreheads. In the years 1870, 1876, and 1877 the author explored Huron ossuaries in Simcoe and Durham Counties and found numerous skeletons in all of them. Artificial mounds or tumuli occur near Rice Lake, Lake Erie, and the Lake of the Woods, and these have yielded copper and pottery.

In the Province of Manitoba numerous grooved stone mauls and hammers, as well as arrow points, stone discs, and pieces of broken pottery, have been found on or near the surface of the ground. In addition to these, the other ancient remains are tumuli of three principal kinds, earthen ridges of great length, and large communal house enclosures. One kind of tumulus contains one or more well-defined burial pits having skeletal remains and manufactured objects of interest, the burial pit being carefully covered and protected by charred wooden poles or by a calcareous layer from four to six inches in thickness, the whole being covered by a great mound of black prairie soil to a height of many feet. Stone circles or cromlechs occur in Saskatchewan near Manitoba.

7. *The present Native Population and Traces of Early Civilisation in the Province of New Brunswick, Canada.* *By* William McIntosh.

The native and half-breed population numbers about fifteen hundred at the present time. These belong to two tribes: the Micmacs, occupying the eastern coast and part of the Bay of Fundy shores, and the Malecites, who inhabit the St. John River Valley, or about the same country which was occupied by their ancestors in early times. They are able to speak English, but use their own language among themselves. The Indians obtain a livelihood by working as millmen, stream driving, lumbering, acting as guides for hunting-parties, making canoes, baskets, butter-tubs, axe handles, etc.

Evidence of the prehistoric occupation of this region by a people who were using implements of stone are abundant. In sheltered coves along the coast are numberless kitchen middens. Along the principal rivers prehistoric camp sites abound. The stone implements, with a few exceptions, are of the type common to the Algonquin areas.

The pottery, in material and shape, closely resembles the ware made by the Algonquin tribes elsewhere, but shows some interesting variations in ornamentation, differing in this respect from the Algonquin pottery of the south. Very little systematic collecting has been done in this region.

Dr. George F. Matthew has studied the kitchen middens and has done surface collecting elsewhere. The result of his work will be found in the Bulletins of the Natural History Society of New Brunswick. Dr. L. W. Bailey has collected and published articles on this subject. S. W. Kain has collected a large amount of material. An account of his work will be found in the Bulletins of the Natural History Society of New Brunswick. Duncan, London, and David Balmain have collected in the St. John River Valley, and the late Dr. Smith, of Tracadie, on the east coast. The author

has collected during the past three years, obtaining over 1,700 pottery fragments and a large number of stone implements. These will be described in the Bulletins of the Natural History Society of New Brunswick. The material collected by Matthew, Kain, McIntosh, and the greater part of the Smith, London, and Balmain collections, are in the Natural History Museum at St. John, N.B. Bailey's and part of London and Balmain's collections are at the University of New Brunswick, Fredericton. Part of the Smith collection is in the Museum at Chatham, N.B.

8. *The Excavations at Sparta of the British School at Athens.* *By* R. M. Dawkins.

(*a*) *Work at the Orthia.*—The sanctuary is now finished. The chief results of the year have been the discovery of walls of the hieron at different periods and fresh light thrown on the earliest periods of the site. The sanctuary occupied what was a natural hollow on the bank of the river, always subject to floods. The cult began certainly as early as the ninth century, and very likely earlier. No trace of anything Mycenean has been found. The earliest thing is a local style of geometric pottery, of which there is so much that its manufacture must have continued unaltered for a very considerable time.

The first trace of cult was in a patch of black ashes mixed with burned fragments of bones and geometric sherds and pieces of bronze all lying on the native soil in the middle of the hollow. Sometime later the hollow was paved in great part with a paving of cobble stones and this paved space surrounded with a wall. Pieces of this wall have been found.

There are no remains of any temple as early as this, just as of the first stage of the hieron represented by the débris below the pavement there are no remains of either temple or altar. The next stage of the hieron shows a considerable development. To it belongs the great archaic altar, the remains of the primitive brick and wood temple, and the great mass of votive offerings extending downwards to the close of the seventh century. The hieron at this period was larger than it had been before. On the east its limit was marked by a wall, which itself, however, belongs to a good deal later date, probably to the sixth century, and on the west the débris of this period were found considerably outside the line of the old wall.

In this condition the hieron must have lasted at least two hundred years (800-600 B.C.). It saw the rise of the Laconian school of vase-painting, and its first two periods, Lac. I and II, and the period of the fine ivory carvings which have been such a feature of this site. They all fall within this period, mostly late in it. At the end of this stage inscriptions begin, *i.e.*, just before 600 B.C.

About the year 600 B.C. there was a change. The primitive temple was destroyed, probably by a flood, and the level of the hieron raised by bringing in a mass of river sand and gravel. The hieron was thus changed from a hollow into a flat-topped artificial mound. On the east side of this an altar was built, of which traces were found and removed, and on the west the great temple. The altar occupies exactly the site of the earlier altar, the temple very nearly. The hieron was now very much larger, and was surrounded by a thick wall. A long stretch of it was found west of the temple, and another piece to the south, close to some Hellenistic houses alongside of the present course of the millstream. The wall between it and the temple to the west is a thin wall, which stood at the edge of the heap of sand to support it. The wall west of the altar also marks the edge of the sand, but it is likely that here also the hieron limit was somewhat wider. The temple was archaic Doric, and the pediment was probably decorated with two lions facing one another in painted sculpture. A small

piece of one of these was found, and two little reliefs representing such a pair of lions.

To the next hundred years (600-500 B.C.) belongs a further mass of votive offerings, found south, west, and north of the sixth-century temple. These comprise the terra-cotta mass, nearly all of which belong to this time, in pottery Laconian III and IV, which embraces nearly all the vases hitherto called Cyrenaic, and a great number of lead votive figurines. The earlier ivory carvings have now given way to work in bone, and the style is not so good. This century marks the beginning of the decline of Laconian art, which is still more marked in the Laconian V and VI, which carry us down to the middle of the fourth century. The greater number of finds of these periods (Lac. V and VI) were from the houses which lie east of the altar, and themselves may be fifth century.

After this the finds are very few: some Hellenistic objects and some Roman terra-cottas. A great many probably were removed when the foundations of the Roman theatre were cut down.

The further history of the site consists of the rebuilding of the temple in Hellenistic times, relics of which are the numerous tiles stamped with the name of the goddess, and finally the building of the Roman amphitheatre in late Roman times for the convenience of spectators. Built into its remains were the inscribed slabs to which were fastened the iron sickles which were the prizes of the victors. The Roman altar stood directly above the earlier ones, and the Roman arena corresponded very well with the old hollow which had seen the beginning of the cult in the very earliest times.

(*b*) *The Menelæum.*—This site had been already partially excavated, first by Ross, and afterwards by Mr. Castriotis. Our attention was drawn to it by a handful of objects found by some shepherds and brought to us. The bunding, supposed to have been the sanctuary of Menelaos and Helen, stands on a hill which rises steeply from the left bank of the Eurotas a couple of miles south of the site of Sparta. The building, as now uncovered, shows itself as a platform surmounted by an oblong structure, which may have been an altar or the base for some conspicuous monument. A ramp gave access to this platform. The structure may be assigned to the fifth century. At a somewhat later date a terrace was added on two sides. In excavating this building some finds were made of Laconian and geometric pottery, and, more important, well below these and below the foundations of the building late Mycenean sherds were found. The chief finds, however, were found on the steep slopes of the hill a little below the building itself. They had clearly got into the position in which we found them from having been thrown down the hill. They comprised pottery of the second Laconian style, badly represented at the Orthia sanctuary, many lead figurines, and a few objects in bone and ivory like those from the Orthia and bronzes. Below these finds, which date from the late seventh century, there was a layer of geometric pottery.

In a field near by we found the remains of a late Mycenean house with painted plaster and pottery, and all about on these hills late Mycenean sherds are to be found. This suggests that the Mycenean Sparta was probably in this region, and it is probably not without significance that the shrine of Menelaos is here rather than on the site of the later city.

---

9. *Report on the Excavation of Neolithic Sites in Northern Greece.*
See Reports, p. 293.

WEDNESDAY SEPTEMBER 1.

The following Papers were read:—

1. *A Study of Malaria in Ancient Italy.*[1] *By* W. H. S. JONES.

---

2. *On a Cult of Executed Criminals in Sicily.* *By* E. SIDNEY HARTLAND, *F.S.A.*

---

3. *The Blackfoot Medical Priesthood.* *By* JOHN MACLEAN.

The author defined medicine men, or, to use a better term, the medical priesthood, as shamans, conjurers, doctors, prophets, and priests, and gave the different grades in the priesthood. The subject of initiation was then dealt with, and the course of instruction was outlined. Previous to this the would-be medicine man undergoes a period of voluntary seclusion, during which he fasts and sees visions. The dress and facial decoration of the fraternity were next described, and the sacred numbers were explained. The subject of disease was next treated, the Blackfeet being particularly prone to small-pox and consumption. The causes of the diseases were discussed, especially the influence which the belief in evil spirits has upon the minds and bodies of the natives.

The author then treated of the medicine man in connection with religion, such subjects as animism, sacred stones, sacrifice, spiritualism, hypnotism, prophecy, and incantation being discussed, as well as medicine songs, charms, and amulets.

Lastly, the author considered native medicines and remedies, and discussed the value of the work of the medicine men among the natives, and the influence exercised by them on the native religion.[2]

[1] Published in *Liverpool Annals of Archæology and Anthropology*, vol. ii., p. 97.
[2] Published in *The Manitoba Free Press*, Winnipeg, September 18, 1909.

Section I.—PHYSIOLOGY.

President of the Section.—Professor E. H. Starling, M.D., F.R.S.

THURSDAY, AUGUST 26.

The following Papers and Report were read:—

1. *Observations on the Osmotic Pressure in the Blood of Fishes.* *By* Professor A. B. Macallum, *F.R.S.*

---

2. *Observations on the Inorganic Composition of the Blood of Fishes.* *By* Professor A. B. Macallum, *F.R.S., and* Dr. C. C. Benson.

---

3. *Report on Anæsthetics.*—See Reports, p. 296.

---

4. *Discussion on Anæsthetics.*

---

5. *On the Use of Atropine or the Allied Drugs Hyoscine, Hyoscyamine, Scopolamine, Daturine, Duboisine, in Conjunction with Anæsthetics.* *By* W. Webster, *M.D., C.M.*

The object of the present research was to test the efficiency of atropine as a restorative in poisoning by chloroform or other anæsthetic, or as a precautionary measure before its administration. The use of atropine in one or other of these ways has been frequently advocated.[1]

A striking discrepancy was noticed between the statements in the text-books and the results actually obtained, and so it was deemed advisable to perform an extensive series of experiments devoted to the physiological effects of atropine and its allies upon the heart, respiration and circulation.

Atropine and the allied drugs mentioned in the title are generally supposed to be isomeric with each other, or very closely allied, and in regard both to their general physiological effects and to the question of the rapidly induced tolerance or immunity described later, all these drugs may be considered as identical.[2]

[1] Schäfer and Scharlieb, *Trans. Roy. Soc. Edin.*, vol. xli. 1901.

[2] For information on the chemistry of these substances see Schmiedeberg, *Pharmakologie*, 1906; Tomasini, *Atti dell. R. Accad. dell. Scienz. Med. Palermo*, Ann. 1896; O. Hesse, Liebig's *Annalen; Bokenham, B.M.J.*, vol. xi. p. 597, 1894; F. R. Pooley, *Can. Lancet*, Jan., 1895; Sharp, *Practitioner*, 1885, 1892, 1893, 1894; *Pharma. Jour.*, 1878.

The question of the value of adrenalin as a restorative to the circulatory system will be incidentally discussed in the body of the paper.

I have performed in all more than eighty experiments—two on cats and the rest on dogs. Chloroform, ether, or the A.C.E. mixture were the anæsthetics used. In some few cases curari has been used in addition. The blood-pressure has been taken from the carotid artery, and the injections made into the saphenous or femoral vein. A glass plethysmograph was used for recording changes in the volume of the limb, and for similar changes in the intestinal wall an air oncometer was used, each of these being connected with a piston recorder. The method described by Oliver and Schäfer [1] was employed for recording the effects upon the heart. A hook is caught in the epicardium of the auricle, and another in the ventricle. From these threads pass over pulleys moving on a horizontal axis; the threads then pass vertically downwards to be attached to long elastic levers of steel. To the ends of the levers writing points are attached.

Physiological Effects.

One of the most familiar, and at the same time most striking, actions of atropine is paralysis of the peripheral terminations of the vagus in the heart. It would naturally be expected that this effect, like section of the vagi, since it cuts off the tonic inhibitory influence of the nerve centre, would exercise an augmentory effect upon the heart and raise the blood-pressure. This is, in fact, usually stated to be the case (see Dixon,[2] Schmiedeberg,[3] and Sollmann [4]). But my own experiments furnish no evidence of any action whatever on the vasomotor system. I have been unable to find any original papers giving details of experiments upon animals, with tracings of blood-pressure.[5]

In my series of more than eighty experiments on dogs, *I have never observed any rise in blood-pressure upon the injection of atropine into the circulation.*[6]

This applies to the allied drugs mentioned in the introduction. The drugs have been tested under very varying conditions as to dosage, amount of fluid injected, temperature of fluid injected, and rate of injection. In all cases, when any effect whatever has been produced, this has been in the direction of a fall of blood-pressure. In small doses this is slight and transient; [7] in large doses marked and long continued—sometimes for an hour. In some cases, however, even after large doses, recovery is fairly rapid.

In many cases, it is true, the tracings show a slight preliminary rise of blood-pressure. This, generally followed by a much more pronounced and significant fall, is, I have convinced myself, simply due to the injection

[1] *Jour. of Physiol.*, vol. xviii. p. 256, 1895.

[2] Dixon, *Manual of Pharmacology*, London, 1906.

[3] *Op. cit.*

[4] Sollmann, *Text Book of Pharmacology*, Philadelphia, 1906.

[5] The literature, however, to which I have access is limited.

[6] Professor Vincent informs me that so far as his memory serves him he has never seen a rise of blood-pressure on the administration of atropine.

[7] A possible criticism of my results would be that doses small enough had not been tried, and that the initial increased rate of heart beat and concomitant rise in blood-pressure, whether due to this or to vaso constriction, had been overlooked. Every precaution has been taken to avoid this error. No dose, however small, has in my dogs produced the slightest rise in blood-pressure. In many cases so small was the amount of drug injected that no effect whatever was produced other than that due to the fluid administered, which point has been very frequently tested by control injections of the same quantity of normal saline solution.

of the fluid in which the drug is dissolved, since an injection of an equal quantity of normal saline solution has been always found to induce a rise of pressure similar in character and of equal magnitude.

Of course, the effect of atropine on the blood-pressure has almost always been recorded in animals already under the effects of other drugs. Thus the animal has been under the effects of chloroform, ether, or A.C.E. mixture when the first dose of atropine, hyoscine, &c., has been injected, and in the experiment in which records of auricle and ventricle were taken, curari was administered in addition.[1] On the other hand, many of the larger doses have been given when the animal has not had any anæsthetic for the previous half-hour, the atropine already used sufficing to maintain an unconscious condition.

Effect upon the Heart.—Contrarily to the usually accepted view, it has been found that in dogs atropine has only at most a very slight and temporary effect in the direction of augmentation of the heart; the chief effect is a diminution in the extent of movement as revealed by the heart levers.

Mode of Action of the Drugs.—The levers of the piston recorders connected with the limb plethysmograph and the intestinal oncometer always fall on the injection of the drug; the limb and intestinal tracings, in fact, passively follow that of the blood-pressure, and frequently show the same preliminary rise as does the blood-pressure.

It would appear that rather too far-reaching deductions have been drawn from the action of atropine in cutting out the inhibitory control of the vagus. Since cutting the vagi always *raises* the blood-pressure, while the administration of atropine always lowers it—in the dog, at any rate—and since on injection of atropine the volume of both limb and intestinal wall always follows passively the blood-pressure, we must conclude that atropine acts upon the heart in a manner quite different from that of section of the vagi. It seems, in fact, that with atropine, although the vagus inhibition is removed, there is a much more powerful effect acting upon the circulation in an opposite sense—namely, a paralytic effect on the heart muscle itself. Dixon says that the muscle of the frog's heart is slightly stimulated. In a few experiments I have performed, I have not been able to verify this.

Action on the Respiratory System.—It is well known that the first effect of atropine upon the respiration is to increase both the frequency and extent of the movements. Subsequently, however, the respiratory centre is paralysed. I have been able to confirm the statement made by Reichert,[2] and quoted by Sollmann,[3] that an animal may recover from many times the minimal fatal dose if artificial respiration be maintained. This power of recovery on the part of the respiratory centre is of supreme practical importance in dealing with cases of poisoning by this drug.

The Effects of rapidly repeated Doses of the Drugs.—It is well known that a very marked tolerance to atropine, as well as to other drugs, can be established both in animals and in man by gradually increasing the dosage over a period of days, weeks, or months. It is, however, somewhat surprising to find that within the limits of time occupied by a single experiment a dog can be brought to withstand, manifesting only a comparatively slight reaction, a dose which, if administered at the beginning of the experiment, would have been certainly and quickly fatal.

[1] In one experiment I have reduced this objection to a minimum by employing only just sufficient anæsthetic for the carrying out of the preliminary surgical proceedings. The animal was then allowed to recover from anæsthesia, and atropine in a small dose injected into a vein. The effect in this case, as usual, was a *fall* and not a *rise* of blood-pressure, and the heart was weakened.

[2] Reichert, *Phila. Med. Jour.*, January 19, 1901.

[3] Sollmann, *op. cit.*

By commencing with small doses and gradually increasing their size, animals of 5 to 12 kg. body weight have, in the course of an experiment lasting one and a half hours, been rendered so immune to the ill-effects of the drug as to tolerate as large a quantity as 0·4 gramme injected intravenously without other apparent ill-effects than a lowering of blood-pressure, from which recovery gradually takes place.

The commencing dose varied from 0·025 mg. to 0·5 mg. of atropine, hyoscine, &c., an injection being given every three to ten minutes afterwards until the animal succumbed. In some cases 0·5 mg. as an initial dose caused death rapidly, but in others 1 mg., or even 2 mg., could be used as an initial dose without a fatal result, the animal showing the same idiosyncrasy as the human subject in this respect. In all cases where the initial dose failed to kill, each successive dose was doubled or trebled, until on many occasions 0·4 of a gramme of the alkaloid was given, and the animal kept alive by artificial respiration, the blood-pressure, which was very low after the injection, rising almost to the normal. But immediately on stoppage of artificial respiration the pressure would fall and death ensue. In later experiments animals have survived this dose without having recourse to artificial respiration.

In my earlier experiments it was impossible to make any definite statement as to the permanent effects of such a dose, as in this and all other cases the animal was killed without being allowed to wake from the anæsthetic. Now, from a further series of experiments it has been ascertained that this immunity applies to the remote as well as to the immediate effects, a number of animals who have received large quantities of the drug—viz., 11 to 12 grs.—being allowed to live for different periods afterwards, some as long as eight days. These animals were then again anæsthetised and an intravenous injection of atropine, of the same amount as the largest dose given at the previous *séance*, administered. The animals all survived this dose, which in some cases amounted to 7 grs., thus showing that the immunity lasts for some time.

It does not make any difference which of the drugs, atropine, hyoscine, hyoscyamine, duboisine, daturine, or scopolamine, are used to commence with in the process of obtaining this tolerance; any one can be used in increasing doses; then, when the dose has become large, an increased dose of any of the others given with no different result than would be obtained were the first drug continued, each drug immunising the animal from all the rest of the series. Further, the serum of an animal which has been rendered immune to large doses of these drugs will, if injected into another animal, confer an immunity on it.

Action of Atropine in Chloroform Poisoning.—'When the blood-pressure has been depressed by an overdose of chloroform, section of the two vagi, by cutting off the medullary effect, will release the heart; the beat will once again recover its normal character, and the blood-pressure will bound up.'[1] A natural inference would be that atropine, by cutting off the tonic effects of the vagus, would have a similar effect. This, however, has not been the case in my experiments.[2] In chloroform poisoning, just as in the normal condition, atropine does not raise the blood-pressure, but lowers it. I have not found the slightest benefit to accrue when atropine has been administered to an animal whose circulation is depressed with chloroform or other anæsthetic.

The use of atropine prior to the administration of chloroform has been strongly advocated and no less strongly opposed by various writers, *e.g.*,

[1] Dixon, *op. cit.*

[2] I have not invariably found benefit from cutting the vagi, though often, as Dixon states, it restores blood-pressure. In the case of one animal, although a sudden rise of blood-pressure took place, respiration was not restored; the blood-pressure again fell, and death rapidly ensued.

Brodie and Crouch,[1] J. Harley,[2] Dastre,[3] Pitha,[4] Fraser,[5] Brown-Sequard,[6] Dastre and Morat,[7] Schäfer,[8] Schäfer and Scharlieb,[9] Hewitt.[10] Some of these question the great danger of primary inhibition of the heart through excitation of the vagus, and also the benefit supposed to be derived from a preliminary dose of atropine.

The dose required to eliminate vagus action in dogs varies greatly per kg. of body weight in different individuals. This variability, we know, exists to as great an extent in the human subject; it follows that after administering a dose of atropine previously determined upon, we are in the dark as to whether we have obtained the desired effect. Should we invariably give a large dose, disagreeable and possibly fatal results might ensue; numerous cases have been recorded where small doses have produced ill effects.

Harley advocates 0·01 to 0·025 grain, and Dastre 0·0015 gramme (0·023 grain). Schäfer,[11] in a paper read last year at Chicago, advocates the use of 1/50 gr. of atropine before all cases of anæsthesia. These doses would certainly cause serious symptoms in some subjects, and would probably cause discomfort in nearly all, and, in spite of their size, we have no guarantee that the quantity is sufficient to abolish vagus action.

Tested upon myself, 0·01 grain administered hypodermically to determine the effect on blood-pressure produced very disagreeable results—headache, defective vision, dryness of the fauces, and a slight inco-ordination of the muscles, particularly of the lower limbs, being the prominent symptoms. The blood-pressure, which was taken previously for three consecutive days at the same hour with Janeway's instrument, was recorded at first every five minutes after the injection, then later every ten minutes. It showed a gradual fall until it was reduced by 20 mm. of mercury. Dr. ——, who was treated in the same manner, but only took 0·0067 grain of atropine, had less pronounced symptoms, but still sufficient to cause considerable discomfort and a very slight change of blood-pressure, which was lowered by 10 mm. of mercury.

So far as I can conclude from my experiments, adrenalin would be of distinctly more benefit than atropine, though, since its effect is transitory, as a rule frequent small doses must be administered in order to be of use. If the heart has not completely stopped, adrenalin causes more active contractions[12] and consequent rise of blood-pressure, which a few doses at short intervals may make permanent. If the heart has ceased absolutely, I have never obtained any result. This restoration of the heart may be obtained after the heart movements can no longer be felt through the chest wall, but when, if the chest wall is opened, small movements can still be observed.

Summary.

1. In dogs atropine, hyoscine, hyoscyamine, scopolamine, duboisine, and daturine produce, whether in small or large doses, a lowering of blood-pressure.

[1] *Trans. Soc. Anæsth.*, vol. vi. pp. 70 and 81, 1903.
[2] *Brit. Med. Jour.*, vol. ii., p. 320, 1868.
[3] *Soc. Biol.*, p. 242, 1883.
[4] Pitha, 1861. Quoted by Schäfer from Dastre.
[5] *Brit. Med. Jour.*, vol. ii. p. 715, 1880.
[6] Brown-Sequard (*C. r. Soc. Biol.*, p. 289, 1883).
[7] Dastre and Morat (*Lyon Med.*, 1882, and *C. r. Soc. Biol.*, pp. 242 and 259, 1883).
[8] Schäfer, *Brit. Med. Jour.* vol. ii. p. 620, 1880.
[9] *Trans. Royal Soc. Edin.*, p. 333, 1904.
[10] *Anæsthetics and their Administration*, pp. 230, 259, 503, 1907.
[11] *Jour. Am. Med. Assn.*, September 8, 1908, vol. li. p. 803.
[12] The rise with adrenalin is due also to stimulation of vaso-motor nerve-endings in various parts of the body.

2. The volume of a limb or portion of intestinal wall always becomes diminished concomitantly with the fall of blood-pressure.

3. The conclusion seems justified that although these drugs eliminate the tonic inhibitory action of the vagus, they have a simultaneous action on the heart substance, diminishing the output. This paralytic effect upon the heart is shown also by direct experiment upon this organ.

4. By frequent administration of increasing doses of these drugs, an animal may be brought into a condition of tolerance within one or two hours, so that at the end of this time it will withstand (with comparatively slight reaction) very many times the dose which would have been fatal at the beginning of the experiments.

5. In small doses the respiration is quickened and rendered deeper. In large doses it is often paralysed immediately.

6. The present series of experiments has not yielded results which would tend to encourage the use of atropine in chloroform poisoning. Adrenalin seems to be of much more, though limited, utility.

FRIDAY, AUGUST 27.

The President delivered the following Address:—

The Physiological Basis of Success.

During past years it has been customary for the Presidents of Sections in their addresses either to give a summary of recent investigations, in order to show the position and outlook of the branch of science appertaining to the Section, or to utilise the opportunity for a connected account of researches in which they themselves have been engaged, and can therefore speak with the authority of personal experience as well as with that imparted by the presidential Chair. The growing wealth of publications with the special function of giving summaries and surveys of the different branches of science, drawn up by men ranking as authorities in the subjects of which they treat, renders such an interpretation of the presidential duties increasingly unnecessary, and the various journals which are open to every investigator make it difficult for me to give in an address anything which has not already seen the light in other forms. The Association itself, however, has undergone a corresponding modification. Founded as a medium of communication between workers in different parts of the country, it has gradually acquired the not less important significance of a tribunal from which men of science, leaving for a time their laboratories, can speak to an audience of intelligent laymen, including under this term all those who are engaged in the work of the world other than the advancement of science. These men would fain know the lessons that science has to teach in the living of the common life. By standing for a moment on the little pinnacle erected by the physicist, the chemist, or the botanist, they can, or should be able to, gain new hints as to the conduct of the affairs of themselves, their town, or their state. The enormous advance in the comfort and prosperity of our race during the last century has been due to the application of science, and this meeting of the Association may be regarded as an annual mission in which an attempt is made to bring the latest results of scientific investigation into the daily routine of the life of the community.

We physiologists, as men who are laying the foundation on which medical knowledge must be built, have as our special preoccupation the study of man. Although every animal, and indeed every plant, comes within the sphere of our investigations, our main object is to obtain from such comparative study facts and principles which will enable us to elucidate the mechanism of man. In this task we view man, not as the psychologist or the historian does, by projecting into our object of study our own feelings and emotions, but by regarding him as

a machine played upon by environmental events and reacting thereto in a way determined by its chemical and physical structure.

Can we not learn something of value in our common life by adopting this objective point of view and regarding man as the latest result of a continuous process of evolution which, begun in far-off ages, has formed, proved, and rejected myriads of types before man himself appeared on the surface of the globe ?

Adaptation.

In his study of living beings the physiologist has one guiding principle which plays but little part in the sciences of the chemist and physicist, namely, the principle of adaptation. Adaptation or purposiveness is the leading characteristic of every one of the functions to which we devote in our text-books the chapters dealing with assimilation, respiration, movement, growth, reproduction, and even death itself. Spencer has defined life as 'the continuous adjustment of internal relations to external relations.' Every phase of activity in a living being is a sequence of some antecedent change in its environment, and is so adapted to this change as to tend to its neutralisation and so to the survival of the organism. This is what is meant by adaptation. It will be seen that not only does it involve the teleological conception that every normal activity must be for the good of the organism, but also that it must apply to *all* the relations of living beings. It must therefore be the guiding principle, not only in physiology, with its special preoccupation with the internal relations of the *parts* of the organism, but also in the other branches of biology, which treat of the relations of the living animal to its environment and of the factors which determine its survival in the struggle for existence. Adaptation therefore must be the deciding factor in the origin of species and in the succession of the different forms of life upon this earth.

Origin of Life.

A living organism may be regarded as a highly unstable chemical system which tends to increase itself continuously under the average conditions to which it is subject, but undergoes disintegration as a result of any variation from this average. The essential condition for the survival of the organism is that any such disintegration shall result in so modifying the relation of the system to the environment that it is once more restored to the average in which assimilation can be resumed.

We may imagine that the first step in the evolution of life was taken when, during the chaotic chemical interchanges which accompanied the cooling down of the molten surface of the earth, some compound was formed, probably with absorption of heat, endowed with the property of polymerisation and of growth at the expense of surrounding material. Such a substance could continue to grow only at the expense of energy derived from the surrounding medium, and would undergo destruction with any stormy change in its environment. Out of the many such compounds which might have come into being, only such would survive in which the process of exothermic disintegration tended towards a condition of greater stability, so that the process might come to an end spontaneously and the organism or compound be enabled to await the more favourable conditions necessary for the continuance of its growth. With the continued cooling of the earth, the new production of endothermic compounds would probably become rarer and rarer. The beginning of life, as we know it, was possibly the formation of some complex, analogous to the present chlorophyll corpuscles, with the power of absorbing the newly penetrating sun's rays and of utilising these rays for the endothermic formation of further unstable compounds. Once given an unstable system such as we have imagined, with two phases, viz. (1) a condition of assimilation or growth by the endothermic formation of new material ; (2) a condition of 'exhaustion,' in which the exothermic destructive changes excited by unfavourable external conditions came to an end spontaneously—the great principle of natural selection or survival of the fittest would suffice to account for the evolution of the ever-increasing complexity of living beings which has occurred in the later history of this globe. The

adaptations, *i.e.*, the reactions of the primitive organism to changes in its environment, must become continually more complex, for only by means of increasing variety of reaction can the stability of the system be secured within greater and greater range of external conditions. The difference between higher and lower forms is therefore merely one of complexity of reaction.

The naked protoplasm of the plasmodium of Myxomycetes, if placed upon a piece of wet blotting-paper, will crawl towards an infusion of dead leaves, or away from a solution of quinine. It is the same process of adaptation, the deciding factor in the struggle for existence, which impels the greatest thinkers of our times to spend long years of toil in the invention of the means for the offence and defence of their community or for the protection of mankind against disease and death. The same law which determines the downward growth of the root in plants is responsible for the existence to-day of all the sciences of which mankind is proud.

The difference between higher and lower forms is thus not so much qualitative as quantitative. In every case, whatever part of the living world we take as an example, we find the same apparent perfection of adaptation. Whereas, however, in the lower forms the adaptation is within strictly defined limits, with rise in type the range of adaptation steadily increases. Especially is this marked if we take those groups which stand, so to speak, at the head of their class. It is therefore important to try and find out by a study of various forms the physiological mechanism or mechanisms which determine the increased range of adaptation. By thus studying the physiological factors, which may have made for success in the struggle for dominance among the various representatives of the living world, we may obtain an insight into the factors which will make for success in the further evolution that our race is destined to undergo.

It is possible that, even at this time, objections may be raised to the application to man of conclusions derived from a study of animals lower in the scale. It has indeed been urged, on various grounds, that man is to be regarded as exempt from the natural laws which apply to all other living beings. When we inquire into the grounds for assuming this anomic, this outlawed condition of man, we generally meet with the argument that man creates his own environment and cannot therefore be considered to be in any way a product of it. This modification or creation of environment is, however, but one of the means of adaptation employed by man in common with the whole living kingdom. From the first appearance of life on the globe we find that one of the methods adopted by organisms for their self-preservation is the production of some artificial surroundings which protect them from the buffeting of environmental change. What is the mucilaginous envelope produced by micro-organisms in presence of an irritant, or the cuticle or shell secreted by the outermost cells of an animal, but the creation of such an environment ? All unicellular organisms, as well as the units composing the lowest metazoa, are exposed to and have to resist every change in concentration and composition of the surrounding water. When, however, a body cavity or *coelom*, filled probably at first with sea-water, made its appearance, all the inner cells of the organism were withdrawn from the distributing influence of variations in the surrounding medium. The coelomic fluid is renewed and maintained uniform in composition by the action of the organism itself, so that we may speak of it as an environment created by the organism. The formation of a body cavity filled with salt solution at once increased the range of adaptation of the animals endowed therewith. Thus it enabled them to leave the sea, because they carried with them the watery environment which was essential for the normal activity of their constituent cell units. The assumption of a terrestrial existence on most parts of the earth's surface involved, however, the exposure to greater ranges of temperature than was the case in the sea, and indicated the necessity for still further increase in the range of adaptation. Every vital process has its optimum temperature at which it is carried out rapidly and effectively. At or a little above freezing point the chemical processes concerned in life are suspended, so that over a wide range of the animal kingdom there must be an almost complete suspension of vital processes during the winter months, and at all times of the year a great dependence of the activity of these processes on the surrounding

temperature. It is evident that a great advantage in the struggle for existence was gained by the first animals which succeeded in securing thermal as well as chemical constancy of environment for their cells, thus rendering them independent of changes in the external medium. It is interesting to note that the maintenance of the temperature of warm-blooded animals at a constant height is a function of the higher parts of the central nervous system. An animal with spinal cord alone reacts to changes of external temperature exactly like a cold-blooded animal, the activity of its chemical changes rising and falling with the temperature. In the intact mammal, by accurately balancing heat loss from the surface against heat production in the muscles, the central nervous system ensures that the body fluid which is supplied to all the active cells has a temperature which is independent of that of the surrounding medium. These are fundamental examples of adaptation effected by creation of an environment peculiar to the animal. Numberless others could be cited which differ only in degree from the activity of man himself. In some parts of this country, for instance, the activity of the beaver in creating an artificial environment has until lately been more marked than that of man himself. We are not justified, then, in regarding mankind as immune to the operation of natural forces which have determined the sequence of life on the surface of the globe. The same laws which have determined his evolution and his present position as the dominant type on the earth's surface will determine also his future destiny.

We are not, however, dealing with or interested in simple survival. Lower forms of life are probably as abundant on the surface of the globe as they were at any time in its history. Survival, as Darwin pointed out, is a question of differentiation. When in savage warfare a whole tribe is taken captive by the victorious enemy, the leaders and fighting men will be destroyed, while the slaves will continue to exist as the property of the victors. Survival, then, may be determined either by rise or by degradation of type. Success involves the idea of dominance, which can be secured only by that type which is the better endowed with the mechanisms of adaptation required in the struggle against other organisms.

Among the many forms of living matter which may have come into being in the earlier stages of the history of the earth, one form apparently became predominant and must be regarded as the ancestor of all forms of life, whether animal or vegetable, viz., the nucleated cell. The almost complete identity of the phenomena involved in cell division throughout the living kingdom indicates that all unicellular organisms and all organisms composed of cells have descended from a common ancestor, and that the mode of its reproduction has been impressed upon all its descendants throughout the millions of years which have elapsed since the type was first evolved. The universal distribution of living cells renders it practically impossible for us to test the possibility of a spontaneous abiogenesis or new formation of living from non-living matter at the present time. We cannot imagine that all the various phenomena which we associate with life were attributes of the primitive life stuff. Even if we had such stuff at our disposal, it would be difficult to decide whether we should ascribe the possession of life to it, and there is no doubt that any such half-way material would, directly it was formed, be utilised as pabulum by the higher types of organism already abounding on the surface of the globe.

Integration and Differentiation.

An important step in the evolution of higher forms was taken when, by the aggregation of unicellular organisms, the lowest metazoon was formed. In its most primitive forms the metazoon consists simply of a cell colony, but one in which all individuals are not of equal significance. Those to the outer side of the mass, being exposed to different environmental advantages from those within, must even during the lifetime of the individual have acquired different characteristics. Moreover, the sole aim of such aggregation being to admit of co-operation by differentiation of function between the various cell units, the latter become modified according to their position, some cells becoming chiefly alimentary, others motor, and others reproductive. Co-operation and differentiation are, however, of no use without co-ordination. Each part of the organism must be

in a position to be affected by changes going on in distant parts, otherwise co-operation could not be effected. This co-operation in the lowest metazoon seems to be carried out by utilisation of the sensibility to chemical stimuli already possessed by the unicellular organism. We have thus co-ordination by means of chemical substances (' hormones ') produced in certain cells and carried thence by the tissue fluids to other cells of the body, a mechanism of communication which we find even in the highest animals, including man himself. To such chemical stimuli we may probably ascribe the accumulation of wandering meso-derm cells—*i.e.*, phagocytes—in an organism such as a sponge, around a seat of injury or any foreign substance that has been introduced. By this mechanism it is possible for distant parts of the body to react to stimulation of any one part of the surface. Communication by this means is, however, slow, and may be compared to the state of affairs in civilised countries before the invention of the telegraph, when messengers had to ride to different parts of the kingdom in order to arouse the whole nation for defence or attack.

Foresight and Control.

Increased speed of reaction and therefore increased powers in the struggle for existence were obtained when a nervous system was formed, by a modification of the cells forming the outer surface of the organism. By the growth of long processes from these cells a conducting network was provided, running through all parts of the body and affording a channel for the rapid propagation of excitation from the surface to the deeper parts, as well as from one part of the surface to another. From this same layer were produced the cells which, as muscle fibres, would act as the motive mechanism of the organism. Thus, from the beginning, the chief means of attack or escape were laid down in close connection with the surface from which the stimuli were received. A further step in the evolution of the nervous system consisted in the withdrawal of certain of the sensory or receptor cells from the surface, so that a specially irritable organ, the central nervous system, was evolved, which could serve as a distributing centre for the messages or calls to action initiated by changes occurring at the surface of the body. At its first appearance this central nervous system would hardly deserve the epithet of ' central,' since it formed a layer lying some distance below the surface, and extending over a considerable area ; though we find that very soon there is an aggregation of the special cells to form ganglia, each of which might be regarded as presiding over the reactions of that part of the animal in which it is situated. Thus in the segmental wormlike animals a pair of ganglia is present in each body segment, and the chain of ganglia are united by longi-tudinal strands of nerve fibres to form the ganglionated cord, or central nervous system.

Such a diffused nervous system, in which all ganglia were of equal value, could, however, only act for the common weal of the whole body when a reaction initiated by stimulation at one part was not counteracted by an opposing reaction excited from another part of the surface. For survival it is necessary that in the presence of danger, *i.e.*, an environment threatening the life of the individual or race, the whole activities of the organism should be concentrated on the one common purpose, whether of escape or defence. This could be effected only by making one part of the central nervous system predominant over all other parts, and the part which was chosen for this predominance was the part situated in the neighbourhood of the mouth. This, in animals which move about, is the part which always precedes the rest of the body, and therefore the part which first experiences the sense impressions, favourable or dangerous, arising from the environment. It is this end that has to appreciate the presence or approach of food material, as well as the nature of the medium into which the animal is being driven by the movements of its body. Thus a predominance of the front end of the nervous system was determined by the special develop-ment at this end of those sense organs or sensory cells which are *projicient*—*i.e.*, are stimulated by changes in the environment proceeding from disturbances at a distance from the animal. The sensory organs of vision, and the organs which correspond to our olfactory sense organs and are aroused by minute

changes in chemical composition of the surrounding medium, are always found especially at the front or mouth end of the organism. The chances of an animal in the struggle for existence are determined by the degree to which the responses of the animal to the *immediate* environment are held in check in consequence of stimuli arising from *approaching* events. The animal, without power to see or smell or hear its enemy, will receive no impulse to fly until it is already within its enemy's jaws. It must therefore be an advantage to any animal that the whole of its nervous system should be subservient to those ganglia or central collections of nerve cells which are in direct connection with the projicient sense organs in the head. This subservience is secured by endowing the head centre with a power, firstly, of controlling and abolishing the activities (*i.e.*, all those aroused by external stimuli) of all other parts of the central nervous system, and, secondly, of arousing these parts to a reaction immediately determined by the impression received from the projicient sense organs of the head, and originated by some change in the surroundings of the animal which has not yet affected the actual surface of its body.

Education by Experience.

The factors which so far determine success in the struggle for predominance are, in the first place, foresight and power to react to coming events, and, in the second place, control of the whole activities of the organism by that part of the central nervous system which presides over the reaction. The animal therefore profits most which can subordinate the impulses of the present to the exigencies of the future.

An organism thus endowed is still, however, in the range of its reactions, a long way behind the type which has attained dominance to-day. The machinery we have described, when present in its simplest form, suffices for the carrying out of reactions or adaptations which are determined immediately by sense impressions, advantage being given to those reactions which are initiated by afferent stimuli affecting the projicient sense organs at the head end of the animal. With the formation of the vertebrate type, and probably even before, a new faculty makes its appearance. Up to this point the reactions of an animal have been what is termed 'fatal,' not in the sense of bringing death to the animal, but as inexorably fixed by the structure of the nervous system inherited by the animal from its precursors. Thus it is of advantage to a moth that it should be attracted by, and fly towards light objects—*e.g.*, white flowers—and such a reactivity is a function of the structure of its nervous system. When the light object happens to be a candle flame the same response takes place. The first time that the moth flies into and through the candle flame, it may only be scorched. It does not, however, learn wisdom, but the reaction is repeated so long as the moth can receive the light stimuli, so that the response, which in the average of cases is for the good of the race, destroys the individual under an environment which is different from that under which it was evolved. There is in this case no possibility of educating the individual. The race has to be educated to new conditions by the ruthless destruction of millions of individuals, until only those survive and impress their stamp on future generations whose machinery, by the accumulation and selection of minute variations, has undergone sufficient modification to determine their automatic and 'fatal' *avoidance* of the harmful stimulus.

The next great step in the evolution of our race was the modification of the nervous system which should render possible the education of the individual. The mechanism for this educatability was supplied by the addition, to the controlling sensory ganglia of the head, of a mass of nervous matter which could act, so to speak, as an accessory circuit to the various reflex paths already existing in the original collection of nerve ganglia. This accessory circuit, or upper brain, comes to act as an organ of memory. Without it a child might, like the moth, be attracted by a candle flame and approach it with its hand. The injury ensuing on contact with the flame would inhibit the first movement and cause a drawing back of the hand. In the simple reflex mechanism there is no reason why the same series of events should not be repeated indefinitely, as in the case

of the moth. The central nervous system, however, is so constituted that every passage of an impulse along any given channel makes it easier for subsequent impulses to follow the same path. In the new nerve centre, which presents a derived circuit for all impulses traversing the lower centres, the response to the attractive impulse of the flame is succeeded immediately by the strong inhibitory impulses set up by the pain of the burn. Painful impressions are always predominant. Since they are harmful, the continued existence of the animal depends on the reaction caused by such impressions taking the precedence of and inhibiting all others. The effect therefore of such a painful experience on the new upper brain must far outweigh that of the previous impulse of attraction. The next time that a similar attractive impression is experienced the derived impulse traversing the upper brain arouses not the previous primary reaction, but the secondary one, viz., that determined by the painful impressions attending contact with the flame. As a result, the whole of the lower tracts, along which the primary reaction would have travelled, are blocked, and the reaction—now an educated one—consists in withdrawal from or avoidance of the formerly attractive object. The burnt child has learnt to dread the fire.

The upper brain represents a nerve mechanism without distinct paths, or rather with numberless paths presenting at first equal resistance in the various directions. As a result of experience, definite tracts are laid down in this system, so that the individual has the advantage not only of his lower reflex machinery for reaction, but also of a machinery which with advance in life is adapted more and more to the environment in which he happens to be. This educable part of the nervous system—*i.e.*, the one in which the direction of impulses depends on past experience and on habit—is represented in vertebrates by the cerebral hemispheres. From their first appearance they increase steadily in size as we ascend the animal scale, until in man they exceed by many times in bulk the whole of the rest of the nervous system.

We have thus, laid down automatically, increased power of foresight, founded on the Law of Uniformity. The candle flame injures the skin once when the finger is brought in contact with it. We assume that the same result will follow each time that this operation is repeated. This uniformity is also assumed in the growth of the central nervous system and furnishes the basis on which the nerve paths in the brain are laid down. The one act of injury which has followed the first trial of contact suffices in most cases to inhibit and to prevent any subsequent repetition of the act.

The Faculty of Speech.

If we consider for a moment the vastness and complexity of the stream of impressions which must be constantly pouring into the central nervous system from all the sense organs of the body, and the fact that, at any rate in the growing animal, every one of these impulses is, so to speak, stored in the upper brain, and affects the whole future behaviour of the animal, even the millions of nerve cells and fibres which are to be found in the human nervous system would seem to be insufficient to carry out the task thrown upon them. Further development of the adaptive powers of the animal would probably have been rendered impossible by the very exigencies of space and nutrition, had it not been for the development of the power of speech. A word is a fairly simple motor act and produces a correspondingly simple sensory impression. Every word, however, is a shorthand expression of a vast sum of experience, and by using words as counters it becomes possible to increase enormously the power of the nervous system to deal with its own experience. Education now involves the learning of these counters and of their significance in sense experience ; and the reactions of the highest animal, man, are for the most part carried out in response to words and are governed by past education of the experience-content involved in each word.

The power of speech was probably developed in the first place as a means of communication among primitive man living in groups or societies ; as a means, that is to say, of procuring co-operation of different individuals in a task in which the survival of the whole race was involved. But it has attained still further

significance. Without speech the individual can profit by his own experience and to a certain limited extent by the control exercised by the older and more experienced members of his tribe. As soon as experience can be symbolised in words, it can be dissociated from the individual and becomes a part of the common heritage of the race, so that the whole past experience of the race can be utilised in the education—*i.e.*, the laying down of nerve tracts—in the individual himself. On the other hand, the community receives the advantage of the foresight possessed by any individual who happens to be endowed with a central nervous system which transcends that of his fellows in its powers of dealing with sense impressions or other symbols. The foresight thus acquired by the whole community must be of advantage to it and serve for its preservation. It is therefore natural that in the processes of development and division of labour, which occur among the members of a community just as among the cell units composing an animal, a class of individuals should have been developed, who are separated from the ordinary avocations, and are, or should be, maintained by the community, in order that they may apply their whole energies to the study of sequences of sense impressions. These are set into words which, as summary statements of sequence, are known to us as the Laws of Nature. These natural laws become the property of the whole community, become embodied by education into the nervous system of its individuals, and serve therefore as the experience which will determine the future behaviour of its constituent units. This study of the sequence of phenomena is the office of Science. Through Science the whole race thus becomes endowed with a foresight which may extend far beyond contemporary events, and may include in its horizon not only the individual life, but that of the race itself, as of races to come.

Social Conduct.

I have spoken as if every act of the animal were determined by the complex interaction of nervous processes whose paths through the higher parts of the brain had been laid down by previous experience, whether of phenomena or of words as symbolical of phenomena. The average conduct, however, of the individual, determined at first in this way, became by repetition automatic—*i.e.*, the nerve paths are so facilitated by frequent use that a given impulse can take only the direction which is set by custom. The general adoption of the same line of conduct by all the individuals of a community in face of a given condition of the environment gave in most cases an advantage to those individuals who were endowed with a nervous system of such a character that the path could be laid down quickly and with very little repetition. Thus we get a tendency, partly by selection, largely by education, to the establishment of reactions which, like the instincts of animals, are almost automatic in character. As MacDougall has pointed out, the representations in consciousness of automatic tendencies are the emotions. Moral conduct, being that behaviour which is adapted to the individual's position in his community, is largely determined by these paths of automatic action, and the moral individual is he whose automatic actions and consequent emotions are most in accord with the welfare of his community, or at any rate with what has been accepted as the rule of conduct for the community.

Rise in Type dependent on Brain.

Thus, in the evolution of the higher from the lower type, the physiological mechanisms, which have proved the decisive factors, can be summed up under the headings of integration, foresight and control. In the process of integration we have not only a combination of units previously discrete, but also differentiation of structure and function among the units. They have lost, to a large extent, their previous independence of action and, indeed, power of independent action, the whole of their energies being now applied to fulfilling their part in the common work of the organism. At first bound together by but slight ties and capable in many cases of separating to form new cell colonies, they have finally

arrived at a condition in which each one is absolutely dependent for its existence on its connection with the rest of the organism and is also essential to the well-being of every other part of the organism.

This solidarity, this subjection of all selfish activity to a common end, namely preservation of the organism, could only be effected by a gradual increase in the control of all parts by one master tissue of the body, whose actions were determined by impulses arising from sense organs which themselves were set into activity by coming events. We thus have with the rise in type a gradually rising scale in powers of foresight, in control by the central nervous system, and in the solidarity of the units of which the organism is composed.

In the struggle for existence the rise in type has depended therefore on the central nervous system and its servants. Rise in type implies increased range of adaptation, and we have seen that this increased range, from the very beginning of a nervous system, was bound up with the powers of this system. Whatever opinion we may finally arrive at with regard to the types of animals which we may claim as our ancestors on the line of descent, there can be no doubt that Gaskell is right in the fundamental idea which has guided his investigations into the origin of vertebrates. As he says, 'the law for the whole animal kingdom is the same as for the individual. Success in this world depends upon brains.' The work by this observer which has lately appeared sets forth in greater detail than I have been able to give you to-day the grounds on which this assertion is based, and furnishes one of the most noteworthy contributions to the principles of evolution which have been published during recent years.

We must not, however, give too restrictive or common a meaning to the expression 'brains' used by Gaskell in the dictum quoted above. By this word we imply the whole reactive system of the animal. In the case of man, as of some other animals, his behaviour depends not merely on his intellectual qualities or powers, to which the term 'brain' is often in popular language confined, but on his position as a member of a group or society. His automatic activities in response to his ordinary environment, all those social acts which we ascribe in ourselves to our emotions or conscience, are determined by the existence of tracts in the higher parts of his brain, access to which has been opened by the ruthless method of natural selection and which have been deepened and broadened under the influence of the pleasurable and painful impressions which are included in the process of education. All the higher development of man is bound up with his existence as a member of a community, and in trying to find out the factors which will determine the survival of any type of man, we must give our attention, not to the man, but to the tribe or community of which he is a member, and must try to find out what kind of behaviour of the tribe will lead to its predominance in the struggle for existence.

Political Evolution.

The comparison of the body politic with the human body is as old as political economy itself, and there is indeed no reason for assuming that the principles which determine the success of the animals formed by the aggregation of unicellular organisms should not apply to the greater aggregations or communities of the multicellular organisms themselves. It must be remembered, however, that the principles to which I have drawn your attention are not those that determine survival, but those which determine rise of type, what I have called success. Evolution may be regressive as well as progressive. Degeneration, as Lankester has shown, may play as great a part as evolution of higher forms in determining survival. The world still contains myriads of unicellular organisms as well as animals and plants of all degrees and complexity and of rank in the scale of life. All these forms are subordinate to man, and when in contact with him are made to serve his purposes. In the same way all mankind will not rise in type. Many races will die out, especially those who just fall short of the highest type, while others by degradation or differentiation may continue to exist as parasites or servants of the higher type.

Mere association into a community is not sufficient to ensure success; there must also be differentiation of function among the parts, and an entire sub-

ordination of the activity of each part to the welfare of the whole. It is this lesson which we English-speaking races have at the present time most need to learn. In the behaviour of man almost every act is represented in consciousness as some emotion, experience or desire. The state of subordination of the activities of all units to the common weal of the community has its counterpart in consciousness as the 'spirit of service.' The enormous value of such a condition of solidarity among the individuals constituting a nation, inspired, as we should say, by this spirit of service, has been shown to us lately by Japan. In our own case the subordination of individual to state interests, such as is necessary for the aggregation of smaller primitive into larger and more complex communities, has always presented considerable difficulty and been accomplished only after severe struggle. Thus the work begun by Alexander Hamilton and Washington, the creation of the United States, is still, even after the unifying process of a civil war, incomplete and marred by contending state and individual interests. The same sort of difficulties are being experienced in the integration of the units, nominally under British control, into one great nation, in which all parts shall work for the good of the whole and for mutual protection in the struggle for survival.

The Lesson of Evolution.

Just as pain is the great educator of the individual and is responsible for the laying down of the nervous paths, which will determine his whole future conduct and the control of his lower by his higher centres, so hardship has acted as the integrator of nations. It is possible that some such factor with its attendant risks of extermination may still be necessary before we attain the unification of the British Empire, which would seem to be a necessary condition for its future success. But if only our countrymen can read the lesson of evolution and are endowed with sufficient foresight, there is no reason why they should not, by associating themselves into a great community, avoid the lesson of the rod. Such a community, if imbued by a spirit of service and guided by exact knowledge, might be successful above all others. In this community not only must there be subordination of individual to communal interests, but the behaviour of the community as a whole must be determined by anticipation of events—*i.e.*, by the systematised knowledge which we call Science. The universities of a nation must be like the eyes of an animal, and the messages that these universities have to deliver must serve for the guidance and direction of the whole community.

This does not imply that the scientific men, who compose the universities and are the sense organs of the community, should be also the rulers. The reactions of a man or of a higher mammal are not determined immediately by impulses coming from his eyes or ears, but are guided by these in association with, and after they have been weighed against, a rich web of past experience, the organ of which is the higher brain. It is this organ which, as the statesman of the cell community, exercises absolute control. And it is well that those who predicate an absolute equality or identity among all the units of a community should remember that, although all parts of the body are active and have their part to play in the common work, there is a hierarchy in the tissues—different grades in their value and in their conditions. Thus every nutritional mechanism of the body is subordinate to the needs of the guiding cells of the brain. If an animal be starved, its tissues waste; first its fat goes, then its muscles, then its skeletal structures, finally even the heart. The brain is supplied with oxygen and nourishment up to the last. When this, too, fails, the animal dies. The leading cells have first call on the resources of the body. Their needs, however, are soon satisfied, and the actual amount of food or oxygen used by them is insignificant as compared with the greedy demands of a working muscle or gland cell. In like manner every community, if it is to succeed, must be governed, and all its resources controlled by men with foreseeing power and rich experience—*i.e.*, with the wisdom that will enable them to profit by the teachings of science, so that every part of the organism may be put into such a condition as to do its optimum of work for the community as a whole.

At the present time it seems to me that, although it is the fashion to acquiesce

in evolution because it is accepted by biologists, we do not sufficiently realise the importance of this principle in our daily life, or its value as a guide to conduct and policy. It is probable that this doctrine had more influence on the behaviour of thinking men in the period of storm and controversy which followed its promulgation fifty years ago than it has at the present day of lukewarm emotions and second-hand opinions. Yet, according to their agreement with biological laws, the political theories of to-day must stand or fall. It is true that in most of them the doctrine of evolution is invoked as supporting one or other of their chief tenets. The socialist has grasped the all-importance of the spirit of service, of the subordination of the individual to the community. The aristocrat, in theory at any rate, would emphasise the necessity of placing the ruling power in the hands of the individuals most highly endowed with intelligence and with experience in the affairs of nations. He also appreciates the necessity of complete control of all parts by the central government, though in many cases the sense organs which he uses for guidance are the traditions of past experience rather than the science of to-day. The liberal or individualist asserts the necessity of giving to each individual equal opportunities, so that there may be a free fight between all individuals in which only the most highly gifted will survive. It might be possible for another Darwin to give us a politic which would combine what is true in each of these rival theories, and would be in strict accord with our knowledge of the history of the race and of mankind. As a matter of fact the affairs of our states are not determined according to any of these theories, but by politicians, whose measures for the conduct of the community depend in the last resort on the suffrages of their electors—*i.e.*, on the favour of the people as a whole. It has been rightly said that every nation has the government which it deserves. Hence it is all-important that the people themselves should realise the meaning of the message which Darwin delivered fifty years ago. On the choice of the people, not of its politicians, on its power to foresee and to realise the laws which determine success in the struggle for existence, depends the future of our race. It is the people that must elect men as rulers in virtue of their wisdom rather than of their promises. It is the people that must insist on the provision of the organs of foresight, the workshops of exact knowledge. It is the individual who must be prepared to give up his own freedom and ease for the welfare of the community.

Whether our type is the one that will give birth to the super-man it is impossible to foresee. There are, however, two alternatives before us. As incoherent units we may acquiesce in an existence subordinate to or parasitic on any type which may happen to achieve success, or as members of a great organised community we may make a bid for determining the future of the world and for securing the dominance of our race, our thoughts and ideals.

The following Papers and Report were then read:—

1. *The Inorganic Composition of the Blood in Puerperal Eclampsia.* *By* Professor A. B. Macallum, *F.R.S.*

---

2. *Report on the Ductless Glands.*—See Reports, p. 293.

---

3. *On the Comparative Anatomy and Histology of the Thyroid and Parathyroid Glands.* *By* Mrs. W. H. Thompson.

---

4. *On the Comparative Physiology of the Thyroid and Parathyroid Glands.* *By* Dr. Brandson *and* Dr. J. A. Halpenny.

MONDAY, AUGUST 30.

The following Papers and Report were read:—

1. *Preliminary Note on the Origin and Function of the Postero-Septal Tract. By* W. Page May, *M.D., D.Sc.*

Aided by numerous microscopical specimens and lantern slides, Dr. Page May gave a description of a descending tract discovered by him some five years before in the brain stem and spinal cord of the monkey. For this nerve path he suggests the name of the postero-septal tract. He demonstrated its presence in several monkeys and dogs and traced its origin and course as presented chiefly by two methods, viz., secondary degeneration according to the Law of Waller, with subsequent staining by osmic acid, and also by retrograde chromatolysis arising in the nerve cells which give origin to the fibres of the tract following upon section of these fibres. He traced the postero-septal tract from its origin in the joint region of the optic thalamus and corpora quadrigemina along chiefly the mesial fillet into the posterior columns of the spinal cord, where it lies symmetrically on either side in close contact with the posterior septum and descends slightly diminishing to the lower thoracic region, where it rapidly terminates in the 10th and 11th thoracic segments.

A series of somewhat detailed experiments with a view to elicit the function of this tract has only so far definitely shown that it is not concerned with the pyramidal or voluntary motor path, nor with any obvious vasomotor processes of the spleen, kidney, and other important organs as examined by the plethysmographic method. As, however, the postero-septal tract is relatively of fair size, its functions must be somewhat important, and is receiving further investigation.

---

2. *Degenerative Changes, with especial reference to the Brain, following Lesions of the Spinal Cord. By* W. Page May, *M.D., D.Sc.*

Dr. Page May demonstrated with microscopic specimens and lantern slides changes which occur in certain cells and groups of cells, more particularly in the brain subsequent to various lesions in the spinal cord and other parts of the central nervous system. These changes were not only shown in the red nucleus, deiters nucleus, and various other groups of cells which give origin to cerebro-spinal fibres and spino-cerebral fibres, but in a joint work by him and Dr. Gordon Holmes had served to delimit the true motor area in the cerebral cortex of the cat, dog, lemur, monkey, chimpanzee, and man. The cerebral cortex in each series of cases was cut in serial section, and according to the period of time allowed to elapse after the lesion, the absence of certain cells or chromatolytic changes in these cells made it easy to map out, in addition to the motor area, the actual cells themselves, which give origin to cortico-spinal fibres. The bearing of this knowledge on clinical work was briefly indicated.

The method of investigation chosen is free from numerous possible fallacies which occur in the stimulation and ablation methods frequently adopted in the past, and which have given many discordant results in the hands of numerous observers. It showed definitely that the cerebral motor area in man and the higher mammals is pre-central, not at all post-central, and in addition gave many important details. Some of these results are in disagreement with statements in regard to the cortical motor area as given even in many recent textbooks, but in the main confirm, and by an entirely different process, the results of Grünbaum and Sherrington in their classical work on the chimpanzee.

---

3. *The Pyramid Decussation in the Sheep.*

By J. Luella King, *A.B.*, *and* Sutherland Simpson, *M.D.*, *D.Sc.*

Very little is known with regard to the course of the pyramid tract fibres in the ungulata. Ziehen,[1] by differential staining with urancarmine and nigrosine, in an uninterrupted series of sections through the bulbar decussation in the sheep, believes that the pyramid fibres after crossing divide themselves into two groups; one passes to the recticular formation in the posterior part of the lateral column, the other goes through the grey matter and turns downwards in the lateral part of the column of Burdach. The posterior horn lies between the two divisions. Kingsbury (from unpublished work) with Weigert staining in the normal sheep, followed the decussated fibres, or many of them, into the posterior column. The results obtained by these methods, however, are not conclusive in tract tracing, since there is no means of knowing the source of the fibres under consideration. Only the developmental or degeneration method is of service.

We have used six adult sheep and two young lambs, but the latter have not yet been examined. After first locating the motor area, which we found to lie in the superior frontal convolution, we extirpated it in the left cerebral hemisphere and followed the resulting degeneration by the Marchi method. The sections above the medulla oblongata have not been carefully examined as yet, and we deal here simply with the decussation.

The degenerated fibres of the pyramid are finer than those in the cat, dog, or monkey. They pass backwards in the raphe toward the central canal, and then, turning abruptly outwards, direct their course through the grey matter to the recticular formation on the antero-lateral aspect of the posterior horn, in the bundles of which they appear to turn downwards. No degenerated fibres can be followed into the funiculus gracilis or funiculus cuneatus in the bulb nor into the columns of Goll or Burdach at a lower level. A large proportion of the fibres—in some sections almost an equal number—instead of crossing the middle line, turn outwards on the same side, and follow a course similar to that described for the crossed fibres. The posterior longitudinal bundles at this level in transverse section show a considerable number of black dots, but whether these represent degenerated fibres from the pyramid tract is uncertain. Below the first cervical segment of the spinal cord we find no evidence of any tract degeneration. The crossed and uncrossed fibres appear to end in the processus reticularis; at all events, we have not succeeded in tracing them beyond this.

The points of interest are—(1) that no pyramid tract, *i.e.*, cortico-spinal, fibres can be followed into the posterior columns; (2) the large proportion of direct to crossed fibres; (3) the fact that the fibres cannot be traced in the spinal cord below the first cervical segment.

---

4. *The Cortico-Spinal Tract in the Guinea-pig.*

By Ida Z. Reveley, *M.A.*, *and* Sutherland Simpson, *M.D.*, *D.Sc.*

The position of the cortico-spinal or pyramid tract shows greater variation than that of any other strand of fibres in the spinal cord. In the majority of mammals that have been investigated (man, monkey, cat, dog, rabbit) its main division—the crossed pyramid tract—lies in the posterior part of the lateral column, but in others—guinea-pig, rat, squirrel—it is said to run in the posterior column. The evidence for this statement is, in many cases, not conclusive, since the course of the fibres has been traced not by the developmental or degeneration method, but simply by following them in serial section through the decussation in the medulla oblongata down into the upper part of the spinal cord.

[1] Ziehen, *Anat. Anz.* Bd. 17, 1900, S. 237.

In our experiments six guinea-pigs were used. A lesion was made involving the whole of the motor cortex in the left cerebral hemisphere and the degeneration from it followed by the Marchi method. Above the decussation nothing calling for special notice was observed except the relatively small area occupied by the transverse section of the pyramids in the medulla oblongata. Fibres begin to cross over from the degenerated pyramid about the level of the calamus scriptorius and continue to do so till the lower level of the medulla is reached. They are found in small but well-defined bundles, which after decussating pass backward through the grey matter, and then turn downward in the funiculus cuneatus, and, to a less extent, in the funiculus gracilis, close to the grey matter. In the first cervical segment they are found in the columns of Burdach and Goll, but a comparatively large proportion disappear in the grey matter of the bulb and probably end there. At the level of the seventh cervical segment they run down close to the postero-mesial border of the neck of the posterior horn and are much less numerous than in the first cervical segment. The number rapidly diminishes caudalwards and at the level of the fourth lumbar segment the tract is represented by not more than half a dozen degenerated fibres. In the sacral region they are entirely absent.

In the lower part of the decussation a very few fibres pass into the posterior column of the same side; these are not evident in the spinal cord below the second cervical segment. No fibres seem to pass into the lateral column of either side and none remain in the anterior column below the decussation. The proportion of crossed to direct fibres is much greater than in the cat, dog, or monkey.

It is important to note that the relation of the fibres of the pyramid tract to the grey matter at the base of the posterior horn is the same in the guinea-pig as in those animals in which they run in the lateral column, the only difference being that in the one case they are placed on its postero-mesial and in the other on its antero-lateral aspect. Another point worthy of notice is the large proportion of fibres which, after crossing, terminate in the grey matter of the medulla oblongata, and the relatively small number which pass down the cord.

---

5. *Ascending Tracts in the Spinal Cord of the Cat.*
By E. G. Peterson, *A.B.*

The object of this investigation was primarily to ascertain whether there is any anatomical evidence for the statement that a certain proportion of the long ascending fibres of the posterior columns of the spinal cord from one side cross the middle line and pass up the corresponding column of the opposite side (Oddi and Rossi,[1] Loewenthal,[2] Van Valkenburg,[3] and others).

The posterior roots were divided between the ganglia and the spinal cord on one side (right) in four cats. In one the fifth lumbar and seventh thoracic roots were cut simultaneously, in the second the fifth lumbar and twelfth thoracic, in the third the fifth lumbar alone, and in the fourth the seventh cervical alone. The resulting degeneration was traced by the Marchi method.

Where the double lesion was made the two zones of degeneration, with a clear area between, can be traced to the medulla oblongata where the fibres of both zones end in the nucleus gracilis. No posterior column fibres are found at a higher level than these nuclei, and none are seen to join the

[1] Oddi and Rossi, *Arch. ital. de Biol.* t. 13, 1890, p. 382.
[2] Loewenthal, *Internat. Monatsch.* Bd. 10, 1893.
[3] Van Valkenburg, *Neurol. Centralb.* 1909, S. 2.

restiform body. Hoche,[1] Schaffer,[2] and Purves Stewart[3] in man found distinct degeneration above the level of these nuclei in the internal and external arcuate fibres of the medulla. Mott[4] and Sherrington[5] found no such fibres in the monkey, and in the cat no trace of any are to be seen. Dydynski[6] states that some fibres from the dorsal columns pass direct through the corpora restiformi to the cerebellum. This is not in agreement with my observations in the cat. All the fibres that reach the bulb terminate in the nuclei of the posterior columns.

In every case there is a symmetrical though much less intense degeneration in the corresponding column of the opposite side, but this is due, in all probability, to some incidental injury to the cord or nerve roots during or subsequent to the operation, since a slight degeneration is also found in the dorsal cerebellar, and, to a less extent, in the ventral cerebellar tracts on both sides. No long fibres can be traced across the middle line from the posterior column on the side of the lesion to that of the other side, although some are found passing into the grey matter of the opposite side through the posterior grey commissure for a few segments above the lesion and many end in Clarke's column of the same side.

In the experiment where the fifth lumbar root alone was divided a well-defined area of degeneration is present in the position of the dorsal cerebellar tract lateral to the entering dorsal root. This can be traced to the cerebellum through the restiform body, but the number of fibres gradually diminishes cephalicwards and only comparatively few reach the cerebellum. Those that disappear in the cord represent proprio-spinal fibres, some of which extend from the lower part of the lumbar region to the upper part of the cervical region. In the cat, therefore, some fibres of the dorsal cerebellar tract take origin as far caudalwards as the fifth lumbar segment, and it may be farther. The fibres in question maintain their position close to the posterior root and the degeneration is not due to the fibres of Gower's bundle finding their way into Flechsig's bundle,[7] since in this specimen no degeneration exists in Gower's tract at any level.

The degeneration from the seventh cervical posterior root was followed to the upper limit of the nucleus cuneatus but no farther.

---

6. *On the Natural Secretion of the Adrenal Bodies.* *By* Dr. F. A. Young.

The elimination of suprarenal activity was attempted by placing ligatures about the vessels to and from the suprarenal capsules. The circulation was thus obstructed for from one to five hours while the blood pressure was recorded in six experiments on dogs.

Practically no fall in the pressure was occasioned.

---

7. *The Opposite Electrotaxis of Animal and Vegetable Cells.* *By* Professor W. M. Thornton, *D.Sc.*

Some years ago (August 1904), whilst examining the influence of an electric field on small elongated bodies suspended in liquids, the author tried diatoms. These orientate quickly under the influence of alternating

[1] Hoche, *Archiv f. Psych. u. Nervenkr.* Bd. 28, 1896, S. 510.
[2] Schaffer, *Arch. f. Mikros. Anat.* Bd. 43, S. 242.
[3] Purves Stewart, *Brain*, vol. 24, 1901, p. 222.
[4] Mott, *Brain*, 1895, p. 1.
[5] Sherrington, *Jour. of Physiol.*, 1893, p. 255.
[6] Dydynski, *Neurol. Cent.*, 1903, S. 898.
[7] Schäfer and Ninian Bruce, *Jour. Physiol. Proc.*, vol. 35, p. xlix.

fields. The movement is identical with that obtained with short inorganic filaments, and is a consequence of the relative electrical conductivity or specific inductive capacity of the body and the surrounding liquid.

To obtain the diatoms a pond scum was used, rich in animal and vegetable organisms. On trying the effect of direct currents the movement was remarkable. Elongated organisms orientated as before into line with the current, but at the same time there were two movements of translation, several animal cells moving against the current—*i.e.*, towards the positive pole—and vegetable cells towards the negative pole. The movement started and stopped instantaneously with the current, and had all the appearance of a forced mechanical action similar to that obtained with inorganic matter. The sliding action of the two kinds across one another in opposite directions was very striking. Separate examination of the organisms gave the same difference, but motility of any kind led to cross effects.

On repeating the experiment recently (June-July 1909) the same results were obtained. Blood cells of any animal and the contents of infusoria were found to move towards the positive pole. The contents of small fresh-water worms moved within the skin in the same direction, clearing the sac at one end or side. Those which moved towards the negative pole were the cells of algæ and bacteria. Filaments of vaucheria anchored at one end and at right angles to the poles moved towards the negative. Out of several hundred observations not more than ten were of doubtful sign. As an example, a unicellular alga was found to move on the glass slide equally well in either direction, the two movements being simultaneous. It was suspected that the cleaning of the slide by rubbing with a cloth electrified its surface, so that when the cells were transferred to it they received other electrification. Passing the slide through a bunsen flame before use removed the surface charge, and the movement was then always to the negative. Paramæcium has been found to move to the negative pole, but ciliates of any kind have both the stimulus to movement of the cilia and that of the cell contents in the above manner. I find that paramæcium always bursts towards the positive pole under the influence of the electric field. All the observed actions reverse when the direction of the current is reversed, and care must be taken to eliminate the effect of streaming under the cover slip.

The effects are so well marked that one is led to hazard the speculation whether the essential difference between animal and vegetable matter is that animal cells are on the whole negatively electrified (and so move to the positive pole), and vegetable cells positively electrified. The difference may extend to the protoplasm.

In support of this there is the fact that the electrical response current in an animal skin is opposite in sign to that in a vegetable skin; one is ingoing, the other outgoing, suggesting an essential difference between the internal electrical states.

It is difficult to find an explanation of the difference in the movement which does not introduce difference in the electrical charge of the cells. There is no change of the shape or dimensions.

In order to observe the effect with certainty it is necessary to use nonmotile cells and an electrical pressure of about 50 volts per centimetre through a thin film of liquid.

---

8. *Causal Factors in the Diurnal Variation in Body Temperature.* *By* Sutherland Simpson, *M.D., D.Sc.*

The temperature of the human body is not constant, but shows a well-marked diurnal variation. The minimum is reached in the early morning some time between two and seven o'clock, and the maximum in the afternoon between four and eight o'clock. The cause of this normal fluctuation

is not understood, but by some it is believed to be simply an expression of the phases of activity and rest through which the body passes in the twenty-four hours.

Muscular exercise, the ingestion of food, the stimulating effect of light, and tissue activity of any kind have a tendency to raise the body temperature, whereas rest and sleep lower it, and the daily temperature rhythm may be the resultant effect of these various influences. If this were so, one would expect to find that, by inverting the daily routine of life, the temperature curve should also be inverted.

Mosso [1] and Benedict [2] have studied the effect of night work and day rest and sleep on the temperature rhythm, and both have come to the conclusion that the normal temperature curve cannot be inverted by inverting the daily routine, for while rest and sleep during the day lower the temperature, work during the night does not raise it appreciably.

These results would appear to show that the daily oscillation of the body temperature is not due directly to the causes already mentioned, but that it may have a deeper significance, and may indicate a diurnal periodicity in the body, comparable in character to the seasonal and lunar changes which are known to occur in certain plants and animals. That a certain fixity of the temperature rhythm is present in the body is the most obvious interpretation of the failure of Mosso and of Benedict to invert it.

Instead of altering the daily routine artificially in a fixed locality, the same may be effected in a natural way by changing the locality, for an individual who travels round the world from west to east, or *vice versa*, especially in high latitudes, quickly alters his daily routine.

It was with the view of finding the effect of such a change of locality on the temperature rhythm that the author made some observations on his own body temperature during a journey eastward from Ithaca, in the western part of the State of New York, to Edinburgh, and westward again from Edinburgh to Winnipeg. Readings were taken from the mouth, axilla, and rectum every three hours from 9 A.M. till midnight, and during the night at irregular intervals whenever the observer happened to wake up. The temperature curve for Ithaca was obtained by recording observations for one week before leaving. The eastward journey was begun on the night of June 25 and Edinburgh was reached at 9 P.M. on July 4; during the voyage Ithaca time was gradually falling behind the local (ship's) time, and at Edinburgh there was a difference of about five hours. If the Ithaca rhythm had been fixed in the body, one would expect to find that the temperature curve should tend to lag behind, so that the sharp morning rise, which was found to occur between 7 and 9, would appear later each successive day, and finally fall between 12 and 2 P.M. in Edinburgh. Such, however, was not the case. The temperature curve seemed to be governed entirely by local time and not by Ithaca time.

Six weeks were spent in Scotland, the journey westward was begun on August 14, Winnipeg being reached on August 27. The difference in time amounts to about seven hours, and it was found, as in the voyage eastward, that the temperature rhythm adjusted itself at once to the change of routine. The temperature curve in Winnipeg differed in no respect from the normal curves in Ithaca and in Edinburgh, and showed no trace of the persistence of an Ithaca or Edinburgh rhythm. This appears to be in agreement entirely with the observations of Gibson [3] and of Osborne,[4] made under somewhat similar circumstances.

[1] U. Mosso, *Arch. Ital. de Biol.*, 1887, viii., p. 177.
[2] Benedict, *Amer. Jour. Physiol.*, 1904, vol. xi., p. 145.
[3] Gibson, *Amer. Jour. of the Medical Sciences*, June 1905, p. 1048.
[4] Osborne, *Jour. Physiol.* (*Proc.*), Jan. 25, 1908.

The effects of changes in the environmental conditions were also studied, and the results will be given when the paper is published *in extenso.*

9. *Report on the Electrical Phenomena and Metabolism of* Arum Spadices.—See Reports, p. 315.

TUESDAY, AUGUST 31.

Joint Discussion with Section B on the Chemistry of Food.—See p. 459.

The following Paper was then read:—

Observations on the Micro-organisms of the Gaertner Group ('Meat-poisoning Bacilli'), with special reference to their Agglutination, Reactions, and their Behaviour on Coloured Substrata. By Professor E. J. McWeeney, *M.A., M.D., D.P.H.*

Professor McWeeney referred briefly to the economic aspect of the subject. Outbreaks of this sort of illness are not uncommon, and are often described as cases of *ptomaine*-poisoning. They are caused by the ingestion of meat that had become infected with micro-organisms of which the prototype was isolated by Gaertner from an outbreak at Frankenhausen in the late 'eighties of the last century, and which are therefore known as the Gaertner group. They are all short bacilli endowed with extremely active mobility. They do not liquefy the nutrient gelatine, and form colonies on it closely resembling those of the ordinary intestinal organism, *bacillus coli communis.* They differ from *bacillus coli,* however, and resemble the typhoid bacillus in their inability to ferment lactose or form indol. Of Gaertner bacilli there are at least two types, the original or true Gaertner, which was isolated by Van Ermengem and his pupils from the outbreaks of meat-poisoning at Rumfleth, Hanstadt, Morseele, &c., and that known as the Flügge-Kaensche, or Aertryk type. These bacilli are also closely allied to, if not identical with, those causing a disease resembling typhoid fever and known as paratyphoid—a disease which is often due to ingestion of specifically infected articles of food.

It would seem as though, when small numbers only of the specific bacilli are present in the infected meat, a general invasion of the organism took place, accompanied by a febrile reaction with a definite incubation period and the symptom-complex known as paratyphoid fever. When, on the other hand, the meat contained a large dose of the virulent metabolic products of the organism, the symptoms came on at once, or after the lapse of a few hours, and speedily ended in death or recovery. In no case could the term ptomaine poisoning be considered applicable to these cases, as the word implies putrefaction, which is certainly neither an essential nor even a usual condition of the meat in these cases. It is often quite fresh.

After briefly referring to the main features of the disastrous outbreak of meat-poisoning at Limerick, which he had occasion to investigate last year, the author said that the conclusions to which he had been led by his study of the bacillus of meat-poisoning were as follows:

1. The particular strain or race of Gaertner bacillus isolated by him from the Limerick case is of high virulence for rats and mice when administered with food. Rabbits succumb to subcutaneous injections not merely of the living bacillus, but also of old cultures heated to 65° C. Very old (nine months) cultures, however, are found to have lost their virulence. A calf aged four months was killed in seven hours by the injection of 20 cubic centimetres of culture-fluid into the jugular vein.

The symptoms were severe dyspnœa, with great rapidity of respiration coming on within a couple of hours after injection, and followed by purging and collapse, with fall of temperature to 97°. Dogs appeared to be immune, and also guinea-pigs—at any rate, to infection by the mouth.

2. The bacillus has a special predilection for the muscular tissue, and can always be isolated from it. Portions of muscle from infected rats and mice communicate the disease to their cage-mates.

3. The bacillus spreads with great rapidity through normal cooked meat. This was tested by placing some of the culture on a slice of cold roast beef, on the top of which were laid a number of other slices, and the whole left to stand till next day at room temperature, when the bacilli were found to have spread through a layer of beef between five and six inches thick.

4. The bacilli of the Gaertner group comprise, in addition to true Gaertner, the Aertryk bacillus, paratyphoid bacillus, and Ratin, which is used for the extermination of rats. After an extensive series of parallel cultures on the several coloured substrata which have been suggested for the detection and differentiation of bacilli of this group, the author was unable to differentiate between them culturally. Neither on Drigalski, Endo, McConkey, Conradi, Fawcus's modification of Conradi, nor on Werbitzki's new china-green medium was he able to detect any constant cultural difference between these organisms.

5. An important practical outcome of this identity is that it is not safe to lay down Ratin for the destruction of vermin in places where the rats which it is proposed to destroy have access to human food.

6. Agglutination tests carried out with the serum of the patients in this case, and also with high potential sera, some made by the writer and some obtained from the Lister Institute through the courtesy of Dr. C. J. Martin, F.R.S., and Drs. McConkey and Bainbridge, have shown a close serological relation between the strain of Gaertner isolated in this case, and typhoid. The relation with paratyphoid bacillus and Ratin is less close. Whether it is really possible, by means of agglutination reactions to differentiate between the individual races or strains of the Gaertner group seems to me doubtful.

7. Inasmuch as in the vast majority of cases infection with these bacilli takes place before the death of the animal, and manifests itself clinically by various septic and suppurative processes, it is absolutely essential, in the interest of the public health, that no carcase should be exposed for sale or sent in on contract to a public institution that has not been slaughtered in a public abattoir and subjected to skilled inspection and, in suspicious cases, to bacteriological examination, which can be quickly and satisfactorily carried out by malachite-green enrichment. Old scraps of meat left over for several days need thorough and prolonged cooking to free them from danger.

WEDNESDAY, SEPTEMBER 1.

The following Papers and Report were read :—

1. *Chloroform Anæsthesia with known Percentage of Vapour Demonstration. By* Dr. N. H. Alcock.

2. *Discussion on the Nucleus.*

3. *Fourth Report on the Effect of Climate upon Health and Disease.*

See Reports, p. 319.

Section K.—BOTANY.

President of the Section:
Lieut.-Colonel David Prain, C.I.E., LL.D., F.R.S.

THURSDAY, AUGUST 26.

The President delivered the following Address:—

Sutor ne supra crepidam judicaret, probably an old saying when Pliny wrote, is still a safe guide. The limitations of life and of knowledge are different, and human effort is thereby so conditioned that progress depends on specialisation in study. Specialisation lessens the temptation to forget this caution; but the force of the proverb is not weakened. It also conveys a behest, and compliance with this behest helps to counteract the narrowed outlook which specialisation sometimes encourages.

Those whose studies are confined to some limited field often welcome a sketch of the aims and methods of work with which they are not familiar. Such a sketch may be held to have served its purpose if the subject discussed, and its relationship to cognate studies, be rendered intelligible.

No apology, therefore, is made for the subject now taken up, even if it be sometimes hinted that this subject—Systematic Botany—is inimical to originality, the antithesis of scientific, and outside the limits of botany proper. These views depend on half-truths and arbitrary connotations. They do not affect the fact that the primary purpose of systematic study is to advance natural knowledge. The systematic worker, in furthering this object, does not halt to consider whether his work be applied rather than original, technical rather than scientific.

As a matter of history, the scope of systematic study practically coincides with what botany once implied; as a matter of fact, it corresponds to what zoology implies now. The accident that man, on his physical side, is like the beasts that perish has led to the recognition of animal physiology and anatomy as independent sciences. Owing to the absence of any such fortuitous circumstance vegetable anatomy and physiology remain under the ancestral roof. These off-shoots of botany are as vigorous as their zoological counterparts. They may be entitled to think that systematic methods are old-fashioned, and it may be desirable that they should set up separate establishments or form alliances with the corresponding off-shoots of zoology. But nothing in all this justifies the eviction of systematic botany from the family home.

The statement that systematic methods are old-fashioned may be accepted without conceding that these methods are out of date. Systematic work, while sharing in the general advance in knowledge, has been able, amid far-reaching changes, to maintain continuity of method in the pursuit of its double purpose. This has been a benefit to botany as a whole when crucial discoveries or illuminating theories have, in other fields, led to a reorientation of view requiring the use of fresh tablets for the record of new results.

Disintegration and readjustment due to altered outlook are familiar processes. Histology, parting company with organography to serve physiology, is now an independent study, one of whose branches occasionally declines to accept any doctrine unconfirmed by cytological methods. The study of problems relating to nutrition and reproduction has been considered the especial task of physiology. Now, the chemist at times claims the problems of nutrition as part of his field, and we look for advances in our knowledge of reproductive problems to the cytologist and the student of genetics. These instances are adduced from without because relative exemption from disintegration is a distinctive feature of systematic study. The two-sided task of the systematist is to provide a census of the known forms of plant life and to explain the relationships of these forms to each other. The work on one side is mainly descriptive, on the other mainly taxonomic, but the two are so interdependent, and their operations so intimately blended, that it is difficult to treat them apart. Reorientation in botanical study has led to seismic disturbances in the taxonomic field, but the materials supplied by descriptive work have remained unaffected, and therefore have been ready for use in the repair or reconstruction of shattered 'systems.'

The exemption from radical change in method, which marks systematic work, is due to those characteristics that expose it to the charges of discouraging originality and of calling only for technical skill. It also largely explains why systematic study, especially on the descriptive side, is not attractive to minds disposed towards experimental inquiry. The labour involved is as exacting, accurate record and balanced judgment are as necessary, in descriptive as in experimental research. 'A skill that is not to be acquired by random study at spare moments' is as essential in descriptive as in other work, while the relief that variation in method affords is precluded. Increased experience, here as elsewhere, leads to more satisfactory results, but without, in this case, mitigating the toil of securing them. The testing of theories, often an inspiring task in experimental research, in the descriptive field retards progress. But if in descriptive work imagination and the spirit of adventure are undesirable, these qualities are not inhibited by systematic study as a whole. Imagination is legitimate and useful in the taxonomic field, and in another line of activity—the acquisition of the material on which descriptive work is based—the spirit of adventure is essential to success.

The untravelled descriptive worker is not without consolations. His work is as necessary to botany as that of the cartographer to geography, or the grammarian to literature. His results are means to the ends that others have in view. If these results often appeal to coming rather than to contemporary workers, the descriptive writer is at least largely spared the doubtful benefit of immediate appreciation. He can pursue his studies unaffected by any considerations save those of adding to the sum of human knowledge and of bringing a necessary task appreciably nearer completion. In descriptive study it is the work rather than the personality of the worker that tells. Yet the work is not without human interest, because systematic writings rarely fail to reflect the character of the writers. The intimate knowledge of descriptive treatises, which floristic or monographic study entails, usually leads to mental estimates of the actual authors. The evidence on which these estimates depend is unwittingly given and unconsciously appreciated. But its value is not thereby diminished, and estimates so formed may prove useful checks on contemporary judgments.

The descriptive worker as a rule makes his work 'the primary business of his life, which he studies and practises as if nothing else in the world mattered.' But he does not hold aloof from those engaged in other lines of botanical activity. His evidence is mainly obtained from organography and organogeny; but, just because his results are for the use of others, the descriptive botanist has to keep abreast of all that is done in every branch of his science. New weapons are constantly being forged, and not in morpho-

logical workshops only; with these and their uses the descriptive worker must be familiar, for the need to employ them may arise at any moment. If he does not always abandon old friends for new, this is not because the systematist is unaware of their existence, or unprepared to apply new methods. The descriptive worker employs his tools as a craftsman; like other craftsmen, he finds that tools do not always fulfil the hopes of their designers. In descriptive work, too, as elsewhere, a steam hammer is not required to break every nut; the staff and sling may be arms as effective as those of the hoplite. There are occasions when the descriptive writer does appear to hold aloof by declining to accept proffered evidence. But his motive is not arrogant; it is only altruistic. If he is to avoid the risk of causing those who depend on his results to reason in a circle, the descriptive writer must obtain these results, if not without extraneous aid, at least without help from those for whose immediate use they are provided.

Taxonomic study is pursued in an environment which differs from that surrounding descriptive work. The descriptive student can hardly see the wood for its trees. The taxonomic student works in more open country, and can look on the wood as a whole. He has, too, the benefit of companionship. The palæobotanist meets him, with all the lore of mine and quarry, as one ready to exchange counsel; other workers attend to give or gather information.

The community of interest which unites the systematic worker, chiefly concerned with existing plant-types, and the palæobotanist, primarily interested in types now extinct, is strengthened by the bond which identity of purpose supplies. But the two are differently circumstanced; the systematic worker is ordinarily better acquainted with the characters than with the relationships of his types; the palæobotanist usually knows more of the relationships of his types than he does, or ever may do, of their characters. The material of the palæobotanist rarely lets him rely on ordinary descriptive methods in defining his plants; he has to depend largely on anatomical evidence, which supplements and confirms, but hardly replaces, the data of organography. On the taxonomic side the palæobotanist is restricted to phylogenetic methods; here again he is handicapped, though less than on the descriptive side, by the fragmentary character of his specimens. The palæobotanist hardly does more than the phylogenist, hardly as much as the anatomist, towards advancing the object all have in common.

The same community of interest unites in their labours the organographic systematist and the morphologist whose interests are phylogenetic. Here, however, though the task of the two be complementary, the mode of attack is so different as almost to mask their identity of purpose. The comparative morphologist studies the planes of cleavage indicated by salient differences in structure and development. The system he evolves is composed of the entities, sometimes more or less subjective, that combinations of characters suggest. The method in intention, and largely in effect, passes from the general to the more particular, though the process is tempered by the fact that the characters used are derived from such types as exhibit them. The organographic systematist, after summing up the characters which mark individual types, aggregates these according to their kinds. Having estimated the features that characterise individual kinds, he aggregates these according to their families. Families are thereafter aggregated in higher groups, and these groups are subjected to further aggregation. The system thus evolved is composed of those entities, always in theory objective, that successive aggregations indicate, and the process is one of constantly widening generalisation.

The comparative morphologist, though glad when his results can be practically applied, follows truth for its own sake. His work is thus on a higher plane than that of the organographic systematist, whose aggregations are primarily utilitarian. But the work of the latter is not less valuable because its scientific character is incidental. Were our knowledge of plant-types exhaustive, a generally accepted artificial arrangement of these would be as

useful to the applied botanist as a professedly natural one. But our knowledge is incomplete, and the accession and intercalation of new types renders any artificial, and most attempts at a natural, system sooner or later unworkable. The more closely an arrangement approximates to the natural system, the less can the intercalation of new forms affect its stability. The more stable a system is, the more easily will its details be remembered and the more useful will it prove in practical reference work. Here, therefore, for once, self-interest and love of truth go hand in hand.

Since the organographic systematist learns their characters from his groups, while the comparative morphologist defines groups by the characters he selects, their results, were knowledge complete, should be identical, and this identity should prove their accuracy. But knowledge is finite, and these results are not always uniform. The want of uniformity is, however, often exaggerated because the reasons are not always appreciated.

One cause is the difference in personal equation, which affects alike the worker who deals with things and him who considers attributes. It would be contrary to expectation were every phylogenist to assign the same value to each character, or every systematist to apply the same limitation to each type or group of types. The divergence of view on the part of two observers may show a small initial angle; it may nevertheless lead them to positions far apart. But while divergence of view is the most obvious explanation of the want of uniformity apparent in systematic results, it is the least effective cause. This inherent tendency to differ manifests itself in contrary directions; in the long run individual variations are apt to cancel each other.

The nature of the work counts for more than the predisposition of the worker. The aggregations on organographic lines, which were the main guides to the composition of the higher groups until phylogenetic study was seriously undertaken, do not assist the comparative morphologist. The characters on which phylogenetic conclusions may be based increase in value in proportion to the width of their incidence, so that the greater their value for phylogenetic purposes the less do they aid the descriptive worker in discriminating between one plant-type and another. Often they are characters which for practical reasons the descriptive worker must avoid. Organography, then, may not give evidence as to characters whereof cognisance cannot be taken, while for another reason the comparative morphologist may not use characters derived from descriptive sources. The object of the phylogenist is to take his share in advancing our knowledge of taxonomy; to seek from the systematist the evidence on which his results are based would be to vitiate the reasoning of both. All that the phylogenist can ask the descriptive worker to do is to supply the units that require classification.

The comparative morphologist, relying mainly on anatomical and embryological evidence, at first had a hope that his method of study might enable him to supply his own units and thereby render further taxonomic work based on organography unnecessary. This hope remains unfulfilled, and the phylogenist, as a rule, limits his efforts to a narrower field. The organographic systematist realises that in the present state of our knowledge the study of the incidence of selected characters gives more satisfactory results as regards the composition of the higher phyla than repeated aggregation can attain, while the comparative morphologist recognises that, as matters stand, the approximations of organography in respect of types and kinds are more satisfactory than any he can yet offer. Since, however, the progress in one case is outwards, in the other the reverse, a zone of contact is inevitable. This zone, in which the influence of both methods of study is felt, is occupied by those groups immediately higher in value than the natural families of plants, and it is here that discrepancies in the results attained chiefly manifest themselves. These discrepancies take the form of unavoidable differences of opinion as regards the composition of collections of natural families. If a family A possesses ten characters of ordinal import, whereof it shares eight

with a family B and only two with a family C, while the characters combined in A are, as regards B and C, mutually exclusive, the organographic systematist is ordinarily induced to group A and B together and to exclude C from that particular aggregation of families. If, on the other hand, the phylogenist finds that the two characters common to the families A and C are met with in other families, D, E, F, he will ordinarily be led to place A, C, D, E, F in the same higher group from which the family B, notwithstanding its greater general agreement with A than any of the others, must be excluded. This source of discrepancy is, however, less potent than might be expected. When the evidence advanced by either is very strong, the other worker readily accepts it; in doubtful cases mutual accommodation takes place, the one worker limiting his groups, the other applying his criteria with less rigidity.

The healthy disregard for formal consistency which admits of adjustments to further practical ends does not, however, alter the fact that a system thus attained can only approximate to the natural arrangement at which both workers aim. Gaps in knowledge may be bridged with histological or teratological aid, or safely crossed with the help of some sudden intuition or happy speculation. But the existence of anomalous types and groups serves as a reminder that much has yet to be learned with regard to living types, while the widest gap in our knowledge of these is a fissure as compared with the chasms that confront the palæontologist. In this the taxonomist of either type finds the incentive to further effort.

The automatic adjustment of differences due to idiosyncrasy, and the mutual accommodation of those arising from method of work, still leave considerable want of harmony in taxonomic results to be accounted for. What appear to be rival systems of classification compete for recognition. As each such system professes to be the nearest attainable approximation to the natural arrangement, the evidence of a state of dissension and confusion in the taxonomic field appears to those unfamiliar with systematic work to be incontrovertible. Dissension may be admitted; confusion there is none. Pictures of the same subject by different artists may be very unlike, yet equally true; what appear to be rival systems are only manifestations of one.

It is not difficult to form a conception of this system; it is less easy to share the conception with others. Let us imagine a closed space approximately spherical in shape, its surface studded with symbols that mark the relative positions of existing plant-types. Let us imagine the lines of descent of all these types to have been definitely traced and effectively mapped. We find, starting from near the centre of our sphere, a radiating system of lines; we find these lines to be subject to repeated dichotomy and embranchment which may take place at any point; we find the resultant lines departing from the original direction at any angle and in any plane; we find the *nodus* of any individual dichotomy or embranchment capable of serving as the focus of origin for a subsidiary system comparable in everything except age with the centre of our sphere, and conceivably exceeding in the multiplicity of its ramifications the primary system itself. Some only of our lines reach the symbols that stud our spherical surface, though every symbol is the terminal of some such line. Here a terminal is fairly isolated, and the line it limits goes far towards the centre with little or no dichotomy or embranchment. Elsewhere our terminals are closely set, the lines they limit running inwards in company till some proximate *nodus* is reached. Moreover, within our sphere, in the abrupt terminals of various lines we can dimly trace the vestiges of other spheres, not always concentric with our present sphere, once studded with symbols marking the existence of types now extinct. Imagine further the centre of our hypothetical space as not necessarily a primary centre, but merely the *nodus* of some dichotomy or embranchment in a system of which ours is but a residuary fragment.

As we are practically limited to superficial delineation, an intelligible picture of our system is more than the science of perspective and the art of

chiaroscuro can be asked to provide. What is unattainable on the flat is still more impossible in sequence. Serial presentation involves a point of departure; convenience, predilection, hazard, may dictate what this shall be, and determine the sequence adopted. The result is not a variety of systems, but a series of variants of one system. Considering how complex the problem is, the number of variants is remarkably small. In any case the differences met with are inconsequent; they do not affect the facts, and the facts alone really count. The trained taxonomist knows that no serial disposition can indicate, even vaguely, the relative position and import of all these facts. Plane presentation, though more adequate than serial by a dimension, falls short of accuracy; the surface on which the bulk of the facts may be displayed can have no lateral boundary. Even if its presentation on a globe be attempted, the diagram must be incomplete; many of the points to be shown lie beneath the surface. Convention might overcome the difficulty involved in the indication of extinct types, but the diagram would still fail by a dimension to demonstrate the descent of the forms superficially represented.

Intercourse with the phylogenist, while directly influencing the relationship of the organographic systematist to taxonomy, has indirectly modified his attitude towards the diagnosis and limitation of plant-types. Taxonomic study based on evidence other than descriptive has stimulated histological research and fired the anatomist with an ambition to replace by his methods those of organography. It is certainly not for want of industry or care that the success of the phylogenist in the taxonomic field has not also attended the diagnostic work of the anatomist. This failure to replace organographic by anatomical methods is due to the fact that the qualities which make histological evidence useful in generalisation lessen its value in discrimination. That anatomical characters may be of great use even in diagnosis has been less fully appreciated than it might by those habituated to organographic methods. On the other hand, anatomists who have not benefited by an apprenticeship in descriptive study at times overlook the fact that the value of histological evidence in diagnostic work is indirect. Codification of the scattered results of systematic anatomy has now shown the descriptive worker how useful histological methods are when skilfully and properly used, and has at the same time made it apparent to the anatomist that, in respect of grades lower than ordinal, his methods are more fitted for proof than for demonstration. Their alliance is now cordial and complete.

While descriptive and anatomical study conjointly make for accurate discrimination, opinion and circumstance combine to prevent uniform delimitation of plant-forms or 'species,' and no conceivable compromise can overcome this difficulty. With the term 'species' is bound up a double controversy—what idea the word conveys, and what entity the word connotes. Into the first we need not enter; we must assume that our ideas are sufficiently uniform to render the term intelligible. The second we cannot take up here; we must accept the position as we find it, and note, in a spirit of detachment, how in actual practice the systematic botanist does delimit his 'species.' In doing this we have to discriminate between the effect which observed facts produce on different minds, and that which different mental states produce on the records of facts. The results obtained may be essentially identical though arrived at in different ways; as, however, the results are not always uniform, the existence and effect of these two factors must be carefully noted.

It is rather unusual to find that workers whose powers of observation are equal take precisely the same view of every member of a group of nearly allied forms. One, from predisposition or accident, is influenced rather by the characters whereby the forms differ; another is more impressed by those wherein they agree. In monographic work especially the same worker may find himself alternately more alive to the affinities and more struck by the discrepancies among related forms. At one time he feels that his difficulties may be best solved by recognising all these forms as distinct, at another he

inclines to the view that they may be but states of one protean species. Where the capacity for detecting differences is naturally strong, the disposition is towards segregation; where there is a keen eye for affinities, the reverse. The facts in both cases are the same; their influence on minds in which the faculty of observation, though equally developed, has a natural bias in a particular direction may thus be different.

This inherent variation in mental quality, of which the observer may personally be unaware, and over which he may have incomplete control, is not, however, so potent a factor as a difference in mental attitude, usually the result of training or tradition. The existence of two distinct attitudes on the part of authors towards their 'species' is common knowledge. In the absence of more suitable terms we may speak of them as the 'parental' and the 'judicial.' To the parental worker his species are children, whose appeals, even when *ad misericordiam,* are sympathetically received. To the judicial worker his species are claimants, whose pretensions must be dispassionately weighed. The former treats the recognition of a species as a privilege, the exercise of which reflects honour. The latter views this task as a duty, the performance of which involves responsibility. With amply characterised forms the mental attitude is inconsequent, but when critical forms are reviewed it is all-important. Here the benefit of a doubt is the practical basis of final decision. This benefit in the case of the parentally disposed worker may lead to the recognition of a slenderly endowed species; in the case of the judicially inclined, to the incorporation of an admittedly critical form in some already described species, the conception of which may thereby be unduly modified.

These attitudes do not in practice divide descriptive workers into two definite classes. Some writers display one attitude at one period, the other at another period of their career. Occasionally the two alternate more than once in a writer's history. Cases are known in which one attitude is consistently adopted towards species of one natural family, the other towards species of a different family.

When want of uniformity in delimitation is due to the varying effect of the same facts on different observers there is no room for either praise or blame. Capacity for appreciating affinities is complementary to that for discrimination. The fact that now one, now the other tendency is more highly developed makes for general progress. Workers in whom the two may be more evenly balanced can strike a mean between the discordant results of colleagues more highly endowed than they are in either direction. But those who possess a capacity for compromise do not mistake this for righteousness; they are apt to wish themselves more gifted with the opposing qualities of those whose work they assess.

When cases in which want of uniformity in delimitation due to difference in mental attitude on the part of independent workers are considered, we again find that praise and blame are inappropriate. If both attitudes have defects to be guarded against, both have merits that deserve cultivation. The defects are patent and rarely overlooked; the careful systematist, more critical of his results than anyone else can be, is alive to the risks which attend stereotyped treatment, and on his guard against the excesses to which this may lead. It is more often forgotten that both attitudes have their uses, and that each should be exhibited at appropriate times. Here, however, no middle way is possible; the mean between the two attitudes has the qualities of a base alloy. It is the attitude of indifference, fatal to scientific progress, and productive of results that are useless in technical research.

The ideal arrangement in monographic study is the collaboration of two workers, one highly endowed with the discriminating, the other with the aggregating faculty. But for the statement of their joint results both must adopt the judicial attitude. On the other hand, in floristic work, in isolated

systematic contributions, and in all descriptive work undertaken on behalf of economic research, the better because the more useful results are supplied by workers in whom capacity and attitude combine to induce the recognition rather than the reduction of easily characterised forms.

In the present state of our knowledge uniformity in the delimitation of what are termed 'species' is unattainable. We are in no danger of forgetting this fact; what we do sometimes overlook is that, circumstanced as we are, such uniformity is undesirable. The wish to be consistent is laudable; when it becomes a craving it blunts the sense of proportion and may lead to verbal agreement being mistaken for actual uniformity. The thoughtful systematist, when he considers this question without prepossession, finds that forms which in one collocation need only be accorded a subordinate position must, under other conditions, receive separate recognition.

The normal effect on specific limitation of the causes that militate against uniformity is easily understood, and the resulting discrepancies can be allowed for in statistical statements. There are, however, cases where the capacity for appreciating differential characters or points of agreement is so highly developed as to obscure or even inhibit the complimentary capacity. The effects are then ultra-normal; nicety of discrimination exceeds the 'fine cutting' allowable in floristic work; aggregation exceeds the limits useful in monography. No common measure is applicable to the results, and the ordinary systematist, who has definite and practical objects in view, expresses his impatient disapproval in unmistakable terms. The work of those addicted to one habit he characterises as 'hair-splitting'; that of those who adopt the other he speaks of as 'lumping.' The industry displayed in elaborating monographs which attribute a thousand species to genera wherein the normal systematist can hardly find a score must often be effort misplaced. The same remark applies to the excessive aggregation that substitutes for a series of quite intelligible forms an intricate hierarchy of sub-species, varieties, sub-varieties, and races. Orgies of reduction are moreover open to an objection from which debauches of differentiation are free. Discrimination can only be effected as the result of study; the finer the discrimination, the closer this study must be. Reduction offers fatal facilities for slovenly work, over which it throws the cloak of an erudition that may be specious. When dealing with excessive differentiation the normal systematist is on solid ground; when following extreme reduction he may become entangled in a morass. Yet workers of both classes only exhibit the defects, for ordinary purposes, of striking merits, and there are occasions when the results that each obtains may be of value to science.

Its mnemonic quality renders taxonomic work practically useful. Its application in economic research does the same for specific determination. Economic workers are chiefly interested in useful or harmful species; to others they would be indifferent were these not liable to be mistaken for such as are of direct interest. The identification of economic species and their discrimination from neutral allies is not always simple, because species that are useful or noxious are often those least perfectly known. The qualities that render them important frequently first attract attention; these may be associated with particular organs or tissues, and samples of these parts alone may be available. Ordinarily, when material is incomplete, critical examination has to be postponed. In economic work, however, this may not be possible, and the systematist, just as in dealing with archæological or fossil remains, may here have to make the most of samples and fragments in lieu of specimens. Cultural help and anatomical evidence sometimes lead to approximate conclusions; often, however, as with neutral species, definite determination must await the communication by the field botanist of adequate material. Even then a difficulty, comparable with that frequently met with in archæological and palæobotanical study, may be encountered. As archæological or fossil material may, owing to the conditions to which it has been

subjected, look unlike corresponding fresh material of the same or similar plants, so may trade samples, owing to special treatment, bear little outward resemblance to the same organs and tissues when fresh.

When material of economic plants is ample another difficulty may be encountered. Domesticated species often undergo perplexing variation. In studying this variation the systematist may have to seek linguistic and archæological help, and be led into ethnological and historical by-paths. In classifying the forms that such domesticated plants assume he gladly avails himself of aid from those whose capacity for detecting affinities is unusually developed. But even with extraneous assistance the systematist, in this field, sometimes fails to attain final results. He can, however, always pave the way for the student of genetics, whose work involves the study of the 'species' as such. As regards forms of economic importance which neither organography nor anatomy can characterise, but which the chemist or biologist can discriminate, physiological methods are required to explain the genesis or elision of qualities evoked or expunged under particular conditions.

A highly developed capacity for aggregation, if properly controlled, is also useful in the study of plant distribution from a physiographical standpoint. The systematist shows his sympathy with phytogeographical needs in two very practical ways. He declines, out of consideration for the geographical botanist, to deal with inadequate material, and for the same reason he refuses, in monographic studies, to be influenced by geographical evidence. The monographer is conscious that if he pronounces two nearly related forms distinct, merely because they inhabit two different areas, he is digging a pit into which the phytogeographer may fall when the latter has to decide for or against a relationship between the floras of these two tracts. But the fact that, with existing knowledge, uniform delimitation of species is impossible, seriously weakens the value of normal systematic results for phytogeographical purposes. The units termed 'species' that are most useful in floristic and economic study are often too finely cut to serve distributional ends. When all existing plant-types have been treated on monographic lines the results may with relative safety be used by the phytogeographer, since errors due to personal equation may be regarded as self-eliminating. As matters now stand, however, the geographical botanist obtains his evidence partly from monographs, partly from floras, and is apt to be misled. Yet even in floristic work the systematist sees that the 'species' which it is his duty to recognise often arrange themselves in groups of nearly allied forms. These groups, which need not be entitled to sectional rank, while very variable as regards the number of species they contain, are more uniform than species in respect of their mutual relationships. They are therefore more useful than species as units for phytogeographical purposes. In defining these groups the faculty for aggregation is essential, and those in whom this faculty is highly developed may here be profitably employed, even when their discriminating powers show a certain amount of atrophy.

The cases, by no means rare, of workers who, with a comparatively poor eye for species, display great talent in their treatment of genera, afford indirect but striking proof that the faculty for aggregation may be more highly developed than its complement, and that the dominance of this faculty may ensure useful results. But the *a priori* expectation that in dealing with families this dominance should be still more valuable is not borne out by experience, for in this case it is recognised that aggregation has probably been pushed too far. This error has not been attributable to the faculty for aggregation so much as to the evidence at its disposal; the corrective has largely been supplied by the use of anatomical methods as supplementary to organographic data.

The physiologist in studying processes is not always obliged to take account of the identity of the plants which are their theatres of action. He has at hand many readily accessible and stereotyped subjects whose identity is a

matter of common knowledge, and as his experience increases he learns that he may sometimes neglect the identity even of these. If he asks the systematist to determine some type on which his attention is especially focussed, the physiologist only does this in order that he may be in a position to repeat all the conditions of an experiment required to verify or modify a conclusion. A passive attitude towards systematic study has thus been created in the mind of the physiologist; this passivity has been intensified by the fact that the direct help which the physiologist can render to systematic study is limited. Physiological criteria are indeed directly applied for diagnostic purposes in one narrow field, where organography and anatomy are synonymous and inadequate. But if it be true that the diagnostic characters on which the bacteriologist relies belong to some non-corpuscular concomitant of his organism, this attempt to apply physiological characters to systematic ends has failed. In many cases physiological characters do influence taxonomic study. Differences in the alternation of generations, specialised habits connected with nutrition, peculiarities as regards response to stimulation, variation in the matter of protective endowments, admit of application in systematic work, and are constantly so applied in the characterisation of every taxonomic grade. But the evidence as to these characters reaches the systematist through secondary channels, so that the help which physiology renders is indirect, and the passivity of the physiologist remains unaffected.

This passivity has at last been shaken by the development of the study of plant distribution from a physiological standpoint. The practical value of this study has been affected by the employment of a terminology needlessly cumbrous for a subject that lends itself readily to simple statement, and by the neglect to explain the status, or verify the identity, of the units included in its plant associations. A reaction against the use of cryptic terms has now set in, and the physiological passivity which has led workers in this field to ignore systematic canons when identifying the units discussed shows signs of disappearing. The œcologist, it is true, must classify his units in accordance with characters that differ essentially from those on which reliance can be placed by the systematist. But the characters made use of must be possessed by his units, and the œcologist now realises that, in effecting his purpose, he is as immediately dependent on descriptive results as the economic worker or the geographical botanist, and that, if his work is to endure, his determinations must be as precise as those of the monographer, his limitations as uniform as those of the phytogeographer. The needs of the œcologist are, however, peculiar, and his units must be standardised accordingly. Œcological units are not the groups of species, uniform as to relationship, which the geographical botanist requires; nor are they the pragmatical 'species' of floristic and economic work. They are the states, now fewer, now more numerous, that these floristic 'species' assume in response to various influences; and œcological associations can only be appreciated and explained when all such states have been accurately defined and uniformly delimited. In accomplishing this task the faculty for detecting differences is the first essential, and the physiologist has here provided a field of study wherein workers, whose tendency to nicety of discrimination unfits them for normal systematic study, may find ample scope for their peculiar talent, and accomplish work of real and lasting value.

We find, then, that the taxonomy of the wider and more general groups is now mainly based on phylogenetic study, and is largely scientific in character and application. The taxonomy of the narrower and more particular groups, based on organographic data supplemented by anatomical evidence, is often somewhat empirical in character, and is largely applied for technical purposes. Among the grades chiefly so applied, the 'species' is a matter of convenience, variously limited in response to special requirements, while the 'family' is a matter of judgment, crystallising slowly into definite form as evidence accumulates. But the 'genus' is relatively stable, and, in con-

sequence of its stability, has long been 'a thing of dignity.' The distinctive air thus imparted to botany is best appreciated when a zoological index is examined.

The use of scientific names, more precise than popular terms and more convenient than descriptive phrases, facilitates the work of reference in applied study. These names are accidents which do not affect the taxonomic status of the units to which they are applied, but do, however, reflect the want of uniformity in the limitation of these units. The non-systematist who has to apply systematic results appreciates that, as knowledge now stands, this is unavoidable, and makes allowance for the state of affairs. But applied workers complain that, in addition to this, descriptive writers show a tendency to care more for names than for the forms they connote, and wantonly alter the designations of familiar forms. The complaint is just, yet the action is not wanton. The tendency in its present form is of recent origin, and, paradoxical as the statement may seem, is the outcome of a wish for uniformity and stability in nomenclature. Of these two qualities the latter is of more importance in applied work, and therefore the more essential. Unfortunately the systematist has given a preponderating attention to the former, and, in his effort to attain a somewhat purposeless consistency, has allowed his science to wait upon the arts of bibliography. He has placed his neck under a galling and fantastic yoke, for nomenclature, though a good and faithful servant, is an exacting and singularly inept master.

To err is human, and the standard of diagnostic work, high as it is, falls short of the standard which the systematic worker desires to attain. It is this fact that explains the remarkable openness of mind, and the great readiness to accept correction, to which systematic study conduces. To this also is attributable the singular freedom of systematic research from the practice of making capital of the fancied shortcomings of fellow-workers. Exhibitions of this commercial spirit are not altogether unknown, and in one narrow field, where systematic results are practically applied, they are sufficiently common to appear characteristic. But they are contrary to the traditional spirit of systematic study, which is uncongenial to the arts of *réclame*.

The subject is by no means exhausted. Time, however, forbids more; but the purpose of this sketch will have been fulfilled if it has helped those whose work lies elsewhere to appreciate more clearly what systematic study tries to accomplish, and to realise the place it fills in the household of our common mistress, the *Scientia amabilis*.

The following Papers were read:—

1. *The Evolution of the Inflorescence. By* J. Parkin, *M.A.*

Apparently little effort has hitherto been put forward to advance the study of the inflorescence beyond the limits of descriptive morphology. In this paper an attempt was made to deal with the inflorescence from the evolutionary standpoint.

The author, from a comparative study of the subject, has been led to believe that *flowers were originally borne on the plant singly, each terminal to a leafy shoot.* Several genera and species, chiefly in those families which for other reasons may be considered primitive, retain for the most part this early and simple arrangement, *e.g., Magnolia, Liriodendron, Calycanthus, Pæonia, Trollius, Adonis, Papaver, Romneya, Kerria,* spp. of *Pyrus, Rubus* and *Rosa.*

From such a shoot bearing foliage leaves below and ending in a single terminal flower, all inflorescences, as well as the solitary axillary flower, are to be derived.

The first step is the formation of the simple cyme, usually a dichasium.—

This is brought about by buds in the axils of some (generally two) of the upper foliage leaves developing and producing lateral shoots, each terminating in a flower, which blooms shortly after that of the main axis. The leaves subtending these lateral (secondary) flowering shoots undergo reduction, eventually becoming *bracts*, and those (two in number, as a rule) borne on the secondary axes themselves are also usually reduced structures, being the precursors of the pair of *bracteoles* so general to the flower stalk (pedicel) of Dicotyledons. Examples showing this initial stage in the evolution of the inflorescence are afforded by *Calycanthus; Pæonia albiflora; Trollius; Rosa,* etc.

An advance from the simple dichasium may come about by the production of tertiary floral shoots from the axils of the leaves (bracteoles) of the secondary ones, and this branching may be continued so as to form higher orders of axes. In this way arise the lax forking inflorescences (compound or *continuous dichasia* they may be called), characteristic of species of *Ranunculus* and *Potentilla,* and especially of the family Caryophyllaceæ. Often the branching progresses at a quicker rate on one side than on the other; if this be accentuated till the branching becomes one-sided from the commencement, a *continuous monochasium* results; and further by the flowers assuming a lateral instead of a vertical position, a *sympodium* comes to be formed. Thus originate the complex sympodial cymose inflorescences of the Boraginaceæ and other families.

The pleiochasium or panicle as the first stage in the evolution of racemose inflorescences.—If the buds in the axils of several leaves on the main axis, instead of only two or three, produce lateral shoots each ending in a flower, a type of inflorescence known as the *pleiochasium* will arise. These secondary axes are generally branched to some extent dichasially. Many of these inflorescences have been grouped under the name *panicle,* the stumbling-block of the descriptive morphologist. The earliest form of this inflorescence is one in which the terminal flower of the main axis expands first; the lateral flowers then open somewhat acropetally. Examples:—*Helleborus fœtidus; Dicentra formosa; Rubus fruticosus; Campanula* spp.

Further steps towards the evolution of true racemose inflorescences take place as follows:—

(1) An increase in the number of laterals, with the result that the terminal flower no longer blooms first.

(2) Suppression of tertiary branching with the production of a raceme with a terminal flower.

(3) Finally the terminal flower, often together with the upper part of the inflorescence, is arrested in its growth, and in the end aborts with the formation of a true raceme.

The evolution of racemose inflorescences according to the above plan has occurred independently in several lines of descent; as examples *Delphinium, Campanula,* and the Fumarioideæ may be mentioned.

Thus, in the author's opinion, *racemose inflorescences have always proceeded from cymose ones, and are therefore, on the whole, a later type.* Hence the Compositæ, usually regarded as the highest group of flowering plants, may be said to have the most evolved kind of inflorescence, the head or *capitulum.* These heads in various members of the family are clustered together so as to form compound inflorescences, which arise phylogenetically in a manner corresponding to what has been shown for simple inflorescences—first cymose aggregates appear, then racemose ones, culminating in the compound head, possessed by the genus *Echinops.*

Solitary Axillary Flowers.—Two kinds at least of these are distinguishable.

(A) The type commonly, but not exclusively, exhibited by climbing and trailing plants, in which single flowers are produced in ascending order from the axils of the foliage leaves. Such an arrangement can be

derived from a pleiochasium, in which the leaves on the main axis have remained largely foliaceous (unreduced). As the climbing habit evolves the flowers will tend to be developed acropetally rather than basipetally, and ultimately the terminal flower will never be produced, for the main axis will continue growing the whole season, throwing off lateral flowers successively from each leaf-axil. These axillary flowers are probably, as a rule, reductions from lateral dichasia. Such an evolution for certain solitary axillary flowers has been suggested by a study of species of *Clematis* and *Convolvulus*.

(B) A second variety of solitary axillary flower occurs in certain arborescent plants. It can be derived directly from the leafy shoot with a solitary terminal flower through the reduction and ultimate elimination of the foliage, together with the shortening of the axis. There is a tendency in many trees and shrubs to transfer the flowers from the terminal and upper shoots to the lower lateral ones (*Calycanthus*, *Rosa*). By reducing such a subordinate shoot to merely the apical flower, a solitary axillary flower will result, provided the tree or shrub be evergreen (*Michelia*, *Illicium*); if, however, it be deciduous, then the flower will appear singly above the leaf-scar on the previous season's growth (*Asimina*, *Chimonanthus*).

Intercalary Inflorescences.—Attention was finally drawn to a kind of inflorescence which has so far received little consideration. It is characterised by the fact that the main axis, after emitting a number of flowers laterally, continues its apical growth vegetatively. The reproductive part of the axis is, therefore, as it were inserted between two vegetative portions. The author proposes the term *intercalary* for such a type of inflorescence. It seems capable of derivation from lateral shoots bearing terminal flowers by grouping these together and by reducing all the leaves to bracts. Examples of intercalary inflorescences are furnished by *Drimys; Choisya*, *Boronia; Calluna*, *Kalmia*; and especially by some of the Australian Myrtaceæ, such as *Callistemon*, *Metrosideros*. If the vegetative continuation of such an inflorescence be arrested, a false terminal one will be formed, as happens sometimes in *Drimys*. Consequently the author suggests that some apparently terminal inflorescences may in reality belong to the intercalary class (probably some Ericaceæ).

2. *The Prothallium and Embryo of Danæa.* *By* Professor DOUGLAS H. CAMPBELL.

In July 1908 a fine series of prothallia and young plants of Danæa was secured in Jamaica. The greater number of specimens belonged to *D. Jenmani*, Underw., but there was a good series of *D. elliptica*, Sm. and a smaller number of specimens of *D. jamaicensis*, Underw. The latter were collected at Morce's Gap; the others in the vicinity of Vinegar Hill, both stations being a few miles distant from the Cinchona Botanical Garden.

The prothallia differed from those of *D. simplicifolia*, Rudge, described by Brebner, in their much larger size and elongated form. Most of the larger ones, which reached a length of 25 mm., were several times longer than wide, and often the posterior end was much attenuated and quite thin, the archegonial cushion not extending into it. Forked prothallia were also found, and one specimen of *D. Jenmani* had four archegonial cushions.

The margin of the prothallium is often deeply lobed like that of Osmunda or Gleichenia. The rhizoids as described by Brebner for *D. simplicifolia* are multicellular.

The archegonia and antheridia resemble in form those of the other Marattiaceæ, but the former are remarkable for the imperfect development

of the ventral canal cell, which in many cases could not be demonstrated at all.

The embryo becomes elongated in the direction of the archegonium axis before division, and at this time resembles that of *Botrychium obliquum*. The first division wall is transverse as in other Marattiaceæ, but the hypobasal cell either does not divide at all or divides only once and forms a short suspensor, all of the organs of the embryo arising from the inner or epibasal cell. The latter undergoes a somewhat irregular quadrant division, the two lower quadrants forming the foot, the upper ones giving rise to the stem apex, the leaf, and later the root.

A single large apical cell can usually be demonstrated in the stem apex at a very early period. No single initial is present in the young leaf, which does not appear to be always formed at the same point.

No trace of the root can be made out until the embryo has reached a considerable size. The root is strictly endogenous in origin, and its single initial cell arises nearly in the centre of the embryo, probably from the stem quadrant. With the elongation of the root downward, it carries with it the foot which covers the growing point of the root like a root-cap.

No cauline bundle is developed in the young sporophyte, the vascular cylinder being made up of the coalescent leaf-traces.

3. *On the Ancestry of the Osmundaceæ. By* R. Kidston, *LL.D., F.R.S., and* Professor D. T. Gwynne-Vaughan, *M.A.*

Lalesskya gracilis and *diploxylon* and *Thamnopteris schlechtendahlii*, from the Permian of Russia, are regarded by the authors as primitive Osmundaceæ. Their conclusions are based upon the structure of the stems and leaf-bases which alone are at present known.

The vascular system of the stem is a protostele with a solid mass of xylem. The xylem is not homogeneous, however, but consists of a stout peripheral zone of normal scalariform tracheæ, surrounding a central mass of short swollen tracheal elements, with porose pitting and probably with more or less thin walls. The petiolar meristeles are C-shaped with the concavity facing towards the axis, and they show a very close resemblance to those of the living Osmundaceæ, even in detail.

It is held that the pith of the modern Osmundaceæ is a true pith, and that it arose by the transformation of the above-mentioned central xylem into thin-walled parenchyma. Later the peripheral xylem ring lost its continuity and became broken up into the separate strands characteristic of the steles of the existing forms.

The Osmundaceæ and the Zygopterideæ are held to be derived from a common ancestor. The vascular system of their stems exhibits a parallel series of developments in the two orders. The typical Zygopterid stele of the Upper Carboniferous has reached a point in advance of that possessed by *Thamnopteris* in so far that most of the central tracheæ have been replaced by parenchyma, although some still retain their tracheal characters, but those of the Lower Carboniferous may be expected to exhibit a stele essentially identical with that of *Lalesskya* and *Thamnopteris*.

4. *Preliminary Note on the Structure of a new Zygopteris, from Pettycur, Fife. By* W. T. Gordon, *M.A., B.Sc.*

Dr. Kidston and Prof. Gwynne-Vaughan have demonstrated a development, among the fossil Osmundaceæ, from a protostelic form to forms which have a well-marked, parenchymatous pith. The Zygopterid stems so far described have either a mixed or a true pith, but no protostelic form has yet been recorded. This new Zygopteris, to which I have given, pro-

visionally, the name *Zygopteris Pettycurensis*, exhibits a distinct protostele, and thus occupies the same position in the Zygopterid alliance that *Thamnopteris Schlechtendalii* does in the Osmundaceous.

The stem of this new species is circular in transverse section. The wood of the stele consists of an inner zone of short, square-ended, reticulately thickened tracheides, and an outer zone of long, pointed, reticulate tracheides, while the protoxylem groups have scalariform thickenings on their walls.

Petioles are given off at long intervals. The petiole trace is elliptical in shape, with a deeply sunk protoxylem group at each end. Islands of parenchyma develop round each of these groups and increase until the trace is broken through at both ends. The trace thus assumes the typical H-shape of the Zygopterid bundle.

The roots come off irregularly and also have two sunken protoxylem groups. The stem branches frequently and in this resembles *Z. corrugata* (Will).

Starting with *Z. Pettycurensis* a series can be established among the Zygopterideæ, which is exactly parallel to that lately shown among the fossil Osmundaceæ. The development in the former group, however, was completed before that in the latter group began, for the Zygopterid series began in the Calciferous Sandstone series, as far as we know, and ended in the Permo-Carboniferous, while the Osmundaceous series began in the Upper Permian and continued on to Tertiary times.

---

5. *The Number of Bacteria in the Air of Winnipeg.* *By* Professor A. H. Reginald Buller, *Ph.D.*, *and* Chas. W. Lowe.

The authors determined the number of bacteria, mould spores, and yeast cells present in the air upon the campus of the University of Manitoba. The observations were made each week throughout a whole year. Both the volumetric and the plate methods were employed. The volumetric method was practically the same as that used by Professor Percy Frankland in London in 1886. Curves were plotted showing the number of micro-organisms present in 10 litres of air, and also the number falling upon a square foot of horizontal surface each minute.

The investigation showed that the maximum number of micro-organisms—namely, 263 in 10 litres of air—occurred on September 28. During the six months November to April inclusive the average number in 10 litres of air was 0·9. It was therefore found that during the winter half of the year the air of Winnipeg is remarkably free from micro-organisms. During two successive weeks in January only two colonies were developed from 100 litres of air in each experiment. The average number of micro-organisms during the summer half of the year, May to October inclusive, was 10·33 in 10 litres. The authors discussed the effects of temperature, rain and snow, wind, and other conditions upon the experimental results.

The number of micro-organisms falling upon a square foot of surface during a minute was found to vary from three in winter to 8,500 on a very windy day in summer.

---

6. *Some Problems connected with the Life History of* Trichodiscus elegans, *Welsford, n.gen. n.s.* *By* Miss E. J. Welsford.

The vegetative filaments of *Trichodiscus elegans* are multicellular and cohere to form a flat pseudo-parenchymatous disc; the free ends of the filaments protrude laterally and bear scattered multicellular hairs; the older

portions of the disc give rise to upright branches. Each cell contains a single parietal chloroplast, a nucleus and a pyrenoid.

Reproduction is by means of megazoospores, microzoospores and isogametes.

The plant is referred to the Chaetopeltideæ section of the Chaetophoraceæ.

A number of individuals were observed growing under similar conditions; some of their cells liberated gametes which fused in pairs; the contents of other apparently homologous structures germinated within the wall of the mother cell to form filaments.

In accordance with the work of Klebs the appearance of the various phases which occur in the life histories of many Algæ has been accounted for by definite changes in the environment.

In *Trichodiscus elegans* such an explanation seems insufficient since different forms of reproduction take place under identical conditions.

---

7. *The New Industry of Rubber Cultivation. By* J. PARKIN, *M.A.*

FRIDAY, AUGUST 27.

The following Papers were read:—

1. *The Chemistry of Chlorophyll. By* Professor R. WILLSTÄTTER.

The older chemical investigations of chlorophyll have dealt with decomposition products too far removed from the natural dyestuff for them to be of real assistance in determining the constitution of chlorophyll. Of permanent value, however, is a fact established by Hoppe-Seyler, and also by Schunck and Marchlewski—namely, that phylloporphyrin, a degradation product of chlorophyll, is closely related to derivatives of hæmin.

Deductions have been drawn from this fact as to the similarity of and close relationship between the pigments of blood and green leaves, but such are unwarranted. Far more important than the similarity of the degradation products is the difference between chlorophyll and hæmin with regard to the metal bound up in a complex manner in their molecules. It is the nature of this metal which conditions the catalytic function of the pigment. The function of hæmoglobin as a carrier of oxygen is to be attributed to its iron content; on the other hand, it is the magnesium in chlorophyll to which an important part in the assimilation of carbon dioxide must be ascribed.

The author has established that the chlorophyll of all classes of plants from the Algæ to the Dicotyledons contains magnesium and no other metal. This has been overlooked previously, possibly because the complex is very sensitive towards acids, which completely eliminate the metal. The metallic complex is far more stable towards alkalis. On heating with potassium hydroxide at 240° magnificent crystalline compounds are obtained which when ignited leave a residue of magnesium oxide amounting to 6 to $7\frac{1}{2}$ per cent.: they are chemically carboxylic acids. The preparation of these well-defined crystalline compounds in a pure state from leaf extracts of various plants has served as a proof for the existence of magnesium in chlorophyll and for the nature of its incorporation in the molecule.

The continued action of alkali yields first green chlorophyllins, which are tricarboxylic acids; then blue glaucophyllin and red rhodophyllin, which are dicarboxylic acids, and finally red pyrrophyllin and phyllo-

phyllin, both monocarboxylic acids. The reaction consists initially of hydrolysis and subsequently in the main of elimination of carbon dioxide. So long as chlorophyll itself was not known in the pure state my method of working consisted in treatment of crude chlorophyll solutions with alkali to determine what acids take away from chlorophyll, and the investigation of the products of the action of acids to ascertain what part of the molecule of the pigment is destroyed by alkalis.

Gentle warming with acids led to the discovery of those constituents of chlorophyll—about 30 per cent. in all—which are lost during alkaline hydrolysis. Chlorophyll contains an aliphatic alcohol of high molecular weight, viz., phytol, $C_{20}H_{40}O$. This is unsaturated, and therefore autoxidisable. Its presence causes chlorophyll to be a wax. Phytol appears to be present in practically constant quantity in the chlorophyll from plants of all orders, yet it is not an essential component of chlorophyll.

In the course of the comparative analysis of the chlorophyll of different plants, for which about 100 species have provisionally served, a few exceptions to the normal composition have been observed. All these exceptions occur in species of *Labiatæ* and *Solanaceæ*. In these exceptions chlorophyll contains no phytol, and accordingly it can be made to crystallise. It has the composition $C_{38}H_{42}O_7N_4$ Mg, gives six per cent. magnesium oxide on ignition, and contains no phosphorus or iron. This crystalline chlorophyll is an ester containing two molecules of alcohol; amorphous chlorophyll contains one molecule of phytol and one of alcohol.

The pure chlorophyll obtained crystalline from Galeopsis, Lamium, Stachys, &c., appears to be the same as crystals observed under the microscope by Borodie in St. Petersburg in 1881. In opposition to Borodie, however, the author considers that the crystalline variety of chlorophyll is relatively rare. Many Labiates and Solanaceæ contain the crystalline, others the amorphous, phytol-yielding variety of chlorophyll. Crystalline chlorophyll is adapted to the quantitative estimation of chlorophyll by colorimetric methods in leaves and plant extracts: it varies between a half and one per cent. of the dried leaf. The foregoing observations were in many cases made on material from dried leaves. It is probable that during drying, &c., the chlorophyll has already undergone change. Such considerations, without affecting what has been already discovered, promise further discoveries when fresh plants are investigated.

---

2. *The Fundamental Causes of Succession among Plant Associations.* *By* Professor Henry C. Cowles.

In the early days of ecological geography little was attempted except the description of the various sorts of plant associations, much as the early taxonomists and morphologists were content to cease their labours when they had described the materials under investigation. At present no taxonomic or morphologic treatise is complete unless the facts presented are related in some way to evolution; the investigation of kinship has replaced the mere collation of unrelated facts.

During the past decade some ecologists have endeavoured to work out the genetic relationships existing among plant associations, and to many of us it has seemed that the first step is the study of the life histories of these associations in each region. In this respect we have been but following in the well-beaten track that has been made by morphologists and taxonomists along the trail blazed by Darwin in 1859. Just as evolution has knit together into a genetic whole the previously isolated phenomena of plant structure, so the evolutionary study of plant associations has shown that what have been regarded as separate entities are often merely stages in development. It has been shown that plant associations are

rarely stable, and that in general 'edaphic formations' (as Schimper termed them) tend to develop into the 'climatic formation' of the particular region studied. For example, east of Manitoba all other associations tend to develop into a mesophytic conifer forest, whereas to the westward all other associations tend to develop into prairie. The author feels, in view of the increasing objection to the use of the terms 'edaphic' and 'climatic,' that it may be well to use such terms as 'proximate' and 'ultimate.' Besides, these terms explicitly imply evolution, which is not the case with the others. Stages between proximate and ultimate may be denominated approximate, mediate, and penultimate.

Having satisfied ourselves of the reality of succession, the next step is the investigation of the underlying causes. It is probable that succession does not take place where there is no essential change in external conditions. Such stability of conditions, however, is extremely rare except in those situations where the ultimate formation has come to full development, or where the proximate and ultimate formations are the same, as in deserts. The simplest as well as the most important changes that bring about succession are those which occur where the topography is stable and are associated more or less directly with the plants themselves.

Wherever plants grow in any abundance there is an accumulation of humus, relatively great in amount in cold, moist climates and small in amount in hot, dry climates. Humus accumulation of necessity induces profound changes in the soil. Foremost among these are changes in water content. On uplands, especially those composed of rock or sand, humus accumulation means an increase of soil moisture, and thus makes possible the development of a vegetation less and less xerophytic, while in depressions such accumulation means decreasing soil moisture and the consequent elimination of hydrophytes. Humus is a further factor in succession in that it furnishes a fit habitat for saprophytes, which make symbiosis possible; it is likely that the late appearance of the beech in the succession series is due in some part to its mycotrophic relations. Recently another possibility has been suggested which may be considered in connection with humus. It appears likely, from experiments on wheat, that root excretions are detrimental to further root activity, especially among plants of the same species. If this is generally true, it is clear that succession is facilitated or even necessitated. Again the increase of humus alters the food conditions in the soil, more and more favouring such plants as require the presence of special organic ingredients. An increase of humus also involves changes in the air content and temperature of the soil that may be of some moment, especially in bogs or moors, plants of mesophytic structure being able to replace the so-called bog-xerophytes.

Scarcely second to humus is the influence of increasing or decreasing shade. Proximate upland associations are exposed to maximum illumination, while each succeeding stage is characterised by an increase of shade, which favours those plants requiring shade for germination and opposes those requiring light. The ultimate formation of any upland will be composed of those plants that can germinate in the densest shade that may there exist. An increase of shade is also accompanied by increasing humidity and soil moisture, thus working in harmony with the humus factors.

Plant invasions influence succession inasmuch as new elements are introduced. Similarly the influence of man on succession is very considerable, partly by reason of the plants which are enabled to invade new regions through his agency, but more by reason of his destructive activities. In nearly every instance man retards the accumulation of humus and increase of shade, thus tending to keep upland associations more xerophytic than would otherwise be the case.

Topographic changes are of profound importance in succession. Winds,

shore currents, and running water are ever destroying here and constructing there. Wind and water erosion cause retrogression from the ultimate toward more proximate stages. However, after retrogression has reached a certain point, continued erosion results in no further change, thus furnishing an interesting instance of change unaccompanied by succession. If erosion ceases, the ordinary successions of stable topography follow. Where winds and waters deposit, there may or may not be succession; for example, the slow deposition of a river commonly favours a rapid advance toward the ultimate formation of the region, while deposition in a dune region may be sufficiently rapid to result in a continuation of the same plant conditions; if deposition slows down or ceases, the ordinary successions of stable topography follow.

Changes in the general climate of a region must influence succession, but such changes are much slower than are those previously mentioned. It is mainly from the geological record that we know of phenomena of this kind. As past climates have become colder or warmer, or drier or moister, respective successions toward more boreal or austral, or more xerophytic or mesophytic formations have taken place.

It seems clear, then, that only when we are dealing with the ultimate formation of a region (the climatic formation of Schimper) is succession unlikely to be found. It also seems clear that succession has many causes, and more than those mentioned are to be expected. Furthermore, in any given succession it is to be expected that two or more causes co-operate, and it is probable that further study will increase the complexity rather than diminish it. Yet another bit is added to this complexity through the fact, just beginning to be realised, that change in external conditions may in many cases result in imperfect succession or no succession at all. A shallow pond that is dominated by an association composed of Proserpinaca, Radicula, Polygonum, and Sium may gradually become a marsh, quite a new condition, and yet be dominated by the same species as before; the plants change their aspect, but remain. Similarly, a spruce bog may gradually develop into a spruce forest, the trees changing in form but not in kind. Even here, however, some species change, and these may be taken as indices of an essential succession, even though the more conspicuous species stay on. Obviously, the determination of the causes of succession and their exact study have but just begun. No more promising lead for the future seems offered, and none to which more may be contributed by exact observation and experiment.

---

3. *The Rocky Mountain Flora as Related to Climate.* *By* Professor Francis Ramaley.

In general an increase of altitude in any one district lowers temperature about three degrees Fahrenheit for each 1,000 feet. The so-called effects of 'altitude' upon plant life are, for the most part, merely the results of diminished heat.

The flora of the Rocky Mountains is much the same from Canada to Colorado, but any particular species must be looked for at higher and higher altitudes as the observer travels to the south. Thus the common 'loco weed' (*Aragallus lamberti*) flourishes at 4,000 to 5,000 feet on the prairies of Alberta and in the foothills near Banff, but does not reach to high altitudes. In Colorado it grows at these lower levels, and is also abundant in the mountain parks at 8,000 or even 9,000 feet.

The mean temperatures for the summer months at Banff (altitude, 4,542 feet) are 46, 52, and 51 degrees Fahrenheit. These are nearly the same as those at stations in Colorado at 9,500 to 10,000 feet. The difference in latitude is about 12 degrees. Roughly speaking, in this case one degree

of latitude corresponds to 450 feet in altitude. The author would not neglect the importance of topographic features in determining a flora, but would emphasise the point that, taken in the large, it is temperature rather than topography, soil, or rainfall which permits or restricts the extension of plants over great areas. The climate of any part of the Rocky Mountains can be easily judged from an examination of the flora.

---

4. *The Porous Cup Atmometer as an Instrument for Ecological Research. By* Professor Burton Edward Livingston.

Introduction.—Evaporation approaches being a summation of the various climatological factors which influence plant behaviour. It is determined primarily by temperature, humidity, and wind velocity, and is usually deeply affected by variations in rainfall and sunshine. A properly constructed atmometer will thus automatically sum the various meteorological elements as they influence the plant, and may be said approximately to integrate the march of plant environment above the soil surface.

From the curve of evaporation for the growing season in any region, together with the rainfall and certain physical data in regard to the soil, the general nature of the vegetation, in an ecological sense, may be quite closely deduced.

In the progress which we are now witnessing toward an answer to the question,—Under what environmental conditions will the different vegetational formations and societies be produced? the measurement of evaporation bids fair to take so important a position that I have thought it might not be untimely to call attention to some of the advantages and difficulties to be met with in the operation of the porous-clay form of atmometer.

Advantages of this Atmometer.—The instrument (first brought to the attention of plant physiologists in Publication No. 50 of the Carnegie Institution) consists essentially of a hollow cup or cylinder of porous clay, so mounted that evaporation of water from its external surface draws more water from the filled interior, which, in turn, is kept filled from a reservoir at a lower level through the principle of the water barometer. The reservoir may be a burette or any suitable vessel, and the amount of water evaporated may be determined from time to time. A recording device has been constructed, which registers on a paper strip the time required to evaporate a unit of water volume, this unit being any convenient one, from 0·2 to 0·3 c.c. to several cubic centimetres.

The main advantages of this form of instrument over the open dish of water are as follows:—

1. The surface of the cup is better exposed to wind action.

2. The evaporating surface is not continually varied by the wind, but remains constant.

3. The relatively large evaporating surface and the relatively small volume of the water contained make the lag due to temperature changes much smaller than it is in the case of the ordinary evaporator pan.

4. This instrument cannot lose water in any way excepting through evaporation; animals do not drink from it, and wind does not spill water over the edge.

5. The porous cup does not trap insects, and thus diminish the evaporating surface.

6. The negative evaporation due to rain is very slight, and may be corrected for if necessary.

7. The form of the cup admits of its simulating to a high degree the evaporation conditions presented by the aerial portions of a plant.

8. The instrument may be placed in almost any conceivable position, as at different heights above the soil surface, &c.

9. The porous cup may be read for much shorter time-periods than can any simple evaporator pan.

Coefficient of Correction for the Porous Cup Atmometer.—This is found by comparing the evaporation rate, under the same conditions, from a given cup and from a standard cup, or from a standard water surface. The effective evaporating surface of every cup is apt to change with use, therefore the method of standardising to standard cups is rather unsafe. In standardising to a free water surface the cups to be standardised are exposed in a room or greenhouse (in the absence of wind) alongside a series of several pans. The latter are of such size and form as to present approximately the same evaporation surface as the cup, the volume of the water contained being automatically kept approximately the same as that of the cup. The entire stand, with pan and constant-level apparatus, is weighed at intervals of twenty-four hours, when the cups are also read. The average loss from the pans is taken as the standard, and is divided by the loss from the several cups respectively, the quotient being the coefficient. When the cups are in use every reading is brought back to standard by multiplying it by the coefficient for its particular cup.

The alteration of the coefficient appears to be due in part to the accumulation of dust upon the clay surface, but in larger part to movements of soluble salts within the wall of the cup. With high evaporation rates the cups often become virtually glazed on the outside, owing to the outward diffusion of these salts and their recrystallisation on the surface. Cups are also often clogged by the growth of micro-organisms within and upon the cup. This occurs with low rates of evaporation, usually only with high humidity.

It is therefore necessary to redetermine the correction coefficient from time to time—at intervals of a month or less. This can be done, without interrupting the series of observations, by simply replacing the cup by a new one which has been standardised, the old one being returned to the laboratory for retesting. The coefficient for any period is either the average coefficient obtained from the original and final tests, or it may be determined by interpolation for the different partial periods as determined by the actual observations. The change in coefficient in a properly operated cup is usually practically negligible for periods not exceeding a month or six weeks, but safety requires that this fact be established for each instrument as it is operated.

The growth of organisms in and upon the cup is prevented by an initial rinsing of the cup on the inside with a solution of mercuric chloride. The small amount of this salt necessary has no effect on the behaviour of the cup.

The cups should be handled without touching the evaporating portion. It is found desirable to coat with melted sulphur, sealing-wax, or shellac the basal portion of the cups, thus giving a safe surface for handling. Of course, nothing but distilled water may be used in all operations with this atmometer.

Treatment of Clogged Cups.—When cups become clogged so as not to be able to transmit water as rapidly as it is demanded by the evaporating power of the air, they may be renewed by removing a thin layer of the clay from the outside. They are first dried, and then scraped with freshly broken glass, or, better, ground on a lathe with a medium grade of sandpaper. Now and then it occurs that this treatment will not suffice, in which case it is best to discard the cup entirely. After scraping or grinding restandardisation is, of course, necessary.

5. *Some Observations on* Spiræa Ulmaria. *By* Professor R. H. Yapp, *M.A.*

In a previous communication[1] the author described the curious seasonal differences, in respect to hairiness, which are to be found in the leaves of *Spiræa Ulmaria.* It was then shown that the leaves unfolded in the spring-time are successively glabrous, partly hairy, and finally densely hairy.

Further observations have shown that in the case of rhizomes, which do not develop into erect flowering shoots, this *increasing* hairiness is only found up to about the middle of July. The leaves unfolded subsequently to this exhibit decreasing hairiness until autumn, when glabrous leaves are again formed.

The author showed that the production, in nature, of glabrous or hairy leaves coincides in a remarkable way with the changes in (1) the evaporating power of the air and (2) light intensity. This is true whether the vertical changes in these factors (due to the density of the vegetation) or the annual march of evaporation and light intensity are considered.

It is difficult to influence the hairiness of *Spiræa* leaves merely by altering the external conditions. But the hairiness is very distinctly reduced by growing the plant in deep shade, if at the same time the atmosphere is constantly kept humid.

---

6. *The Delayed Germination of Seeds.* *By* Professor L. H. Pammel.

In 1901 the author began a study of the germination of weed seeds kept under different conditions. It was soon discovered that a large number of weed seeds failed to germinate in the fall as they should, and a more extended work was begun in 1902, keeping some of the weed seeds in paper packages, while others were stratified in sand and subjected to the environmental conditions of an Iowa winter. Mr. H. S. Fawcett, under my direction, made a study of a large number of weed seeds. He found on germinating seeds each month from November until May, and another sample in May which had been exposed to the weather, that the general effect of the freezing and thawing was to increase the percentage of germination, especially of seeds with hard coats; stratification lessened also the dormant period in the case of wild rye from nine to five days; the common fox-tail (*Setaria glauca*) from eleven to seven and a quarter days, while the percentage germination of this plant was increased from 34½ to 38 per cent.

Subsequently the author and Miss Charlotte M. King made a study of the germination of seeds of 130 species of weeds. As in the previous experiment, seeds were placed in paper packages and planted each month. Another lot was stratified in sand and subjected to an Iowa winter. The experiment was started in the fall of 1905, continuing until April 1909. The germination of the seeds was remarkably low during all the months, but in most instances the germination was better in samples stratified in sand than those kept in paper packages. Many of the seeds germinated in a very irregular manner, better in some years than others. It is evident that the factors influencing the germination of many of our weed seeds and species of plants are not known. A study was also made of old clover seed. It was found that the scratching of clover seed and treatment with sulphuric acid in some cases hastened the process of germination, but not in all.

Finally, it was found with reference to the soft maple (*Acer saccharinum*) that this seed soon loses its vitality, but that it may be kept for weeks in a refrigerator without materially losing its vitality. The thin seed-coats cause a rapid loss of water from the cotyledons, and hence

[1] Brit. Assoc. Rep., Leicester Meeting, 1907, p. 691.

destroys its vitality. This is especially true of such seeds as those exposed to a drier atmosphere.

7. *The Perception of Light in Plants.* By HAROLD WAGER, *F.R.S.*

It is well known that various plant organs exhibit a definite response to the action of light. Free-swimming organs, such as zoospores, move towards or away from the source of light. Orthotropic organs, such as young seedlings, stems, and roots, bend towards or away from the light, whilst diatropic organs, such as foliage leaves, place themselves at right angles to the direction of the light.

It was shown by C. and F. Darwin in 1880 that the illumination of one part of the sensitive organ determines the movement in another part; that one part of the sensitive organ perceives the light and that a stimulus is set up which is transmitted to another part, where the movement takes place. In ordinary foliage leaves the leaf blade is usually the perceptive region, the movement being brought about by the petiole.

It is clear that the object of these heliotropic movements is either to protect the plant from a too intense light or to bring it into such a position that it can take the fullest advantage of the light which falls upon it. There can be no doubt that this is effected with considerable precision. But how it is that the plant is enabled to perceive that it is or is not in the right position, and the means by which the light stimulus is set up, are not yet clearly understood.

In the case of free-swimming organisms, such as Chlamydomonas, Euglena, &c., it is probable that the eyespot or its equivalent is the percipient organ. The light rays absorbed by the eyespot are those which are functional in heliotropism, and these may act in some way upon the flagellum either directly or through the cytoplasm, and so bring about the necessary modification of its movements by which the course of the organism is changed.

In dia-heliotropic foliage leaves Haberlandt suggests that the epidermal cells or special modifications of them function as ocelli or rudimentary eyes by converging the light so as to bring about a differential illumination of the cytoplasm on the basal wall of the epidermal cells, by means of which the stimulus is set up.

The layer of cytoplasm lining the epidermal cells would, therefore, in this case be the percipient organ. The evidence in favour of this view is, however, not very satisfactory and has been recently criticised, both on morphological and physiological grounds.

As an alternative to this view, it is suggested that the chlorophyll grains are the percipient organs. It is well known that they are sensitive to light, and that in some cases they show this by definite responsive movements. The unequal illumination of the chlorophyll grains when the rays of light fall upon the leaf in a slanting direction would be sufficient to account for the generation of the stimulus, and it is possible that the optical behaviour of the epidermal cells may be of importance in this respect. The rays of light which are absorbed by the chlorophyll are the only ones which appear to be functional in heliotropism, and these by their action upon the various colouring matters contained in the chlorophyll may set up in the cytoplasm immediately adjacent changes necessary to bring about the stimulus.

MONDAY, AUGUST 30.

Joint Discussion with Section B and Sub-section K (Agriculture) on Wheat.—See Appendix A.

TUESDAY, AUGUST 31.

The following Papers and Reports were read:—

1. *The Production, Liberation, and Dispersion of the Spores of Hymenomycetes.* By Professor A. H. REGINALD BULLER, *Ph.D.*

The number of spores liberated by large fruit-bodies amounts to thousands of millions. A specimen of *Psalliota campestris* with a diameter of 8 cm. was found to produce 1,800,000,000 spores, one of *Coprinus comatus* 5,000,000,000, and one of *Polyporus squamosus* 11,000,000,000. The rate of elimination of the spores or young plants by death can be shown to be enormous. The most prolific kind of fish is not so prolific as a mushroom plant. It was estimated that a large fruit-body ($40 \times 28 \times 20$ cm.) of *Lycoperdon bovista,* Linn, the giant puff-ball, contained 7,000,000,000,000 spores, or as many as would be liberated by 4,000 mushrooms, each having a diameter of 8 cm.

With the unaided eyes by daylight, clouds of spores were observed to be given off continuously for thirteen days from the underside of a large fruit-body of *Polyporus squamosus.* It was found that each hymenial tube was liberating spores from every part of its hymenium.

Spores falling from any fruit-body suspended in a suitable glass chamber, *e.g.* a closed beaker, can be seen in clouds or individually without magnification by using a concentrated beam of light. Much use was made of this discovery in the research.

The beam-of-light method can be used to make a very simple and effective laboratory demonstration of the discharge of spores from mushrooms, &c. It may be carried out with great convenience at any time by using as material the mature xerophytic fruit-bodies of *Lenzites betulina, Schizophyllum commune, Polystictus versicolor,* &c. These can be kept dry in bottles for months or years. After wet cotton-wool has been placed above them they quickly revive, and they begin to shed their spores within six hours. The emission of the spores continues for days.

The four spores on each basidium are discharged successively within a few seconds or minutes of one another.

Each spore is shot out violently to a distance of about $\frac{1}{10}$ mm.

The rate of fall of spores in still air was determined for the first time. A small piece of a fruit-body was placed in a vertically-disposed compressor cell. The falling spores were observed with a horizontal microscope, and their rate of fall accurately recorded upon a revolving drum.

The first direct test of the applicability of Stokes' Law to the fall of microscopic spheres in air has been carried out by determining the size, specific gravity, and terminal velocity of the spherical spores of *Amanitopsis vaginata.* The rate of fall of the spores was found to be about 46 per cent. greater than was expected. While, therefore, the observed speed has proved to be of the same order of magnitude as the calculated, Stokes' Law has not been confirmed in detail. No fully satisfactory reason for the discrepancy between theory and observation has so far been found.

The rate of fall of hymenomycetous spores ranges from 0·3 to 6·0 mm. per second. It varies with the size of the spores, their specific gravity, and the progress of desiccation. The relatively very small spores of *Collybia dryophila* in very dry air were found to fall at an average rate of 0·37 mm. per second, whilst the relatively very large spores of *Amanitopsis vaginata* in a saturated chamber attained a speed of 6·08 mm. per second. The spores of the mushroom (*Psalliota campestris*), shortly after they have left the pileus, fall at a speed of approximately 1 mm. per second.

The importance of violent spore-discharge lies in the fact that thereby the very adhesive spores are prevented from touching one another or any part of the hymenium whilst escaping from the fruit-body. Each spore is shot out more or less horizontally into the spaces between the gills, in hymenial tubes, &c. The horizontal motion is very rapidly brought to an end owing to the resistance of the air. In consequence of this, and also of the attraction of gravitation, the spore describes a sharp curve and then falls vertically downwards.

The path of the spore between the gills, in tubes, &c., has been called the *sporabola*, and is remarkable in that it appears to make a sudden bend approximately through a right angle. When for any spore the terminal vertical velocity and the maximum horizontal distance of discharge have been determined, its sporabola becomes amenable to a satisfactory mathematical treatment.

In the agaricineæ there are two distinct spore-producing and spore-liberating types of fruit-body—the *Coprinus comatus* type and the mushroom type. These differ from one another in several structural and developmental details.

In the Coprini 'deliquescence' is a process of autodigestion which renders important mechanical assistance in the process of spore-discharge. It was more especially studied in the case of *Coprinus comatus*. The spores on each gill ripen and are discharged in succession from below upwards. Autodigestion leads to the removal of those parts of the gills which have already shed their spores and thus permits of the continued opening out of the pileus. By this means the necessary spaces for the violent discharge of the spores from the basidia are provided. The spores, after describing sporabolas, fall vertically downwards between the gills. On emerging from the pileus they are scattered by the winds. 'Deliquescence' is in no way connected with the visits of insects to the fruit-bodies.

---

2. *The Destruction of Weeds in Field Crops by Means of Chemical Sprays. By* Professor Henry L. Bolley.

This paper cited the fact that spraying for the control of fungi and insects has developed but slowly along lines directed chiefly by simple trial experiments. There has been in this work but slight real investigation upon biological effects or relations either as affecting the host or the parasite.

Noting that since he introduced the work of field-spraying for control of weeds in cereal crops the idea is being widely accepted and applied under greatly varying conditions of the crop, weeds, and season, the author called attention to the great possibilities involved in the process, both for crop improvement and crop production.

It calls for no mere spraying of a few vegetables, a vine, or a few trees at a time, but is directed upon the crops of greatest field extent and monetary value—wheat, corn, oats, flax, barley, pasturage, hay lands, park ways, &c. The possible cost of the process far exceeds that of any other type of spraying yet undertaken.

For this reason alone the author thinks that this work of great agricultural import should not be left to the slow process of development by trial, or to the energetic but wild propaganda of chemical and spraying machine companies. Mistakes which may involve the yield of great wheat areas are too costly. Exact investigations, chemical, physical, and physiological, involving the effects of the various sprays upon the biology of the weeds and the crop plants should be undertaken, so that experimenters may be able to give quite explicit explanations of the results

which may be expected under the particular conditions under which the farmer must work.

Considering the fact that empirical trials will tend to establish the most simple conditions of usefulness, the following lines of investigation were cited as most likely to promote a normal and efficiently rapid development of the process: (1) The exact nature of the chemical or chemicals employed; (2) the substances in the weeds and crop plants most likely or apt in physical, chemical, or physiological action; (3) the relation of the particular reactions as influenced by atmospheric moisture, soil moisture, sunlight and heat; (4) the action of the sprays as influenced by the chemical type of the soil, and the age of the plants to be treated; (5) the spread of reaction between the cropping plant and the weed concerned as evidenced in susceptibility to the sprays, and as shown in structural and physiological differences; (6) the form of spray most suited to do the work in each particular case; (7) what organisms are concerned other than the cropping plants and the weeds attacked.

---

3. *Some Effects of Tropical Conditions on the Development of certain English Œnotheras.* *By* Dr. R. R. Gates.

The seeds for these cultures were obtained from near Liverpool, England, through the kindness of Dr. D. T. MacDougal, and the first culture was planted in the tropical greenhouse at the University of Chicago, July 1907. Fifty-six plants were grown in this culture, and soon there were seen to be two distinct series of rosettes, one of which proved to be derivatives of *O. Lamarckiana*[1] and the other of *O. grandiflora*. The former, which included just half the culture, produced a variety of forms, including types very closely related to the mutants of De Vries, and others quite different from them. All but six of these continued in the rosette stage, and were still rosettes when the culture was discontinued in May 1909, nearly two years after it was begun.

During the twenty-two months of the culture many of the rosettes continued producing cycle after cycle of rosette leaves above, the old leaves dying away below. This was accompanied by a great amount of growth of the stem in thickness and some growth in length, but no internodes were formed. The result was a stem, in one or two cases eight or ten inches high, having a striking similarity to the appearance of a cycad, with its surface covered with leaf bases and leaf scars arranged in diagonal series and surmounted by a crown of rosette leaves. Several plants of this *O. Lamarckiana* series, after producing a considerable leaf-base area, finally, in October and November 1908, sent up a stem of the ordinary type. These stems showed marked fasciation, and the branches were few, irregular, and high up on the stems. The same applies to a less extent to the *O. grandiflora* derivatives. The main stem, particularly when fasciated, often drooped over and grew horizontally or downwards for a time, later growth being erect again.

The other half of this culture is of special interest, because I have shown them to be derived from *O. grandiflora*. The rosettes are markedly different from those of any of the *O. Lamarckiana* series. Several types of leaves succeed each other as the rosette develops. In the tropical culture, in the final rosette stage, the leaves have deep lobes at their base. This stage is entirely omitted when the plants are grown under ordinary conditions, as shown by my cultures this year at the Missouri Botanical Gardens, from offspring of the plants in this culture, as well as from seeds

[1] As already known from Charles Bailey, Manchester Mem. 61, No. 11, 1907, and MacDougal, Carnegie Pub. No 81, 1907.

direct from the English locality. In no case did these lobes appear in any of the rosettes. Instead, a loose rosette is formed, consisting of a few leaves of the type which preceded the lobed type of leaf in the tropical culture. In many cases, however, no rosette whatever was formed, the plants already having a stem several inches high when small seedlings three months old. The plants of this series in the tropical culture remained in the rosette stage until June 1908, or about ten months. During the summer of 1908 they sent up tall, slim stalks, branching very little except at the top.

Incidentally it might be said that there is no tendency in the offspring of the tropical culture to inherit the tendency to produce the type of rosette leaf with basal lobes.

4. *The Organisation and Reconstruction of the Nuclei in the Root-tips of* Podophyllum peltatum. *By* Professor JAMES BERTRAM OVERTON.

Although nuclear divisions have been frequently studied, a detailed investigation of the behaviour of the chromosomes during rest has, until recently, been largely neglected. A number of valuable papers have appeared, notably, those of Von Wisselingh, Grégoire, and his students, Haecker, Strasburger, and Bonnevie, so that general interest has increased.

Most authors hold that the chromatin is the bearer of the hereditary qualities. In the resting nucleus there appear two stainable substances, the linin framework, in which the more stainable chromatic corpuscles are impregnated or supported. When the chromosomes become visible these corpuscles, or whatever they may be called, become arranged in linear series into a ribbon or spirem. By a fission of these bodies and of the substratum a perfect division of the hereditary qualities results. Grégoire admits the presence of two substances, but maintains that the chromatin does not exist as granules, but that it impregnates the linin. He finds the reticulum equally stained, except at the junctures in the young regions of the root-tip, and therefore concludes that the chromatin entirely impregnates the linin in these nuclei. In older regions one can recognise true chromatin spheres, resulting simply by a massing at certain points. In the spirem he believes the so-called chromomeres are only the nodal structures due to alveolisation, the whole band being chromatic with denser portions.

The reticulum of the resting nucleus results, according to Gégoire, by the lateral anastomosing of the telophase chromosomes. These anastomoses arise as marginal portions of the chromosomes, which are at first always in contact, and by the transformation of each chromosome, by means of a gradual alveolisation, into alveolar reticulate bands or elementary reticula. The final nuclear reticulum, therefore, is composed of a number of elementary reticula in juxtaposition. During the prophases a recondensation occurs to form the chromosomes of division. This interpretation has been confirmed by Kowalski, Berghs, Ulano, Haecker, and the Schreiners.

I have endeavoured to follow in detail the changes which the telophase chromosomes undergo during their passage into the resting nucleus, and to follow carefully their structure and arrangement in the resting nuclei of the root-tips of *Podophyllum peltatum*, and also to determine how the visible chromosomes are reformed preparatory to division.

During the passage of the chromosomes from the equatorial plate to the poles they become more or less irregularly vacuolated, appearing more transparent in spots. This appearance gradually increases until conspicuous anastomosing vacuoles appear on the inside. I have never found the chromosomes so completely massed or crowded as described by some authors for other plants. The chromosomes often touch each other laterally at

certain points, due, perhaps, to their increased size, brought about by the vacuolisation. These telophase chromosomes become arranged into a spirem, as usually described, before the formation of the complete nuclear reticulum. The progressive vacuolisation continues until each chromosome becomes very much enlarged. The vacuoles, which are of various shapes and sizes, seem to run into each other laterally, thus forming eventually a reticulum from each chromosome. It appears as though certain portions of each chromosome were being dissolved and replaced by a liquid substance, leaving a true reticulum. I believe that each chromosome is composed of chromatic granules, closely massed in a linin substratum. By means of the progressive vacuolisation these chromatic granules are separated. Not all of the linin disappears in this process, so that a reticulum of linin supporting the chromatic granules remains. The whole process, so far as I have been able to observe, never begins from the outside, but is always internal. I have never found the lateral anastomoses of marginal portions, described by Grégoire, in well-fixed preparations. I have followed each chromosome to complete reticulation, and discovered traces of each chromosome in the resting nucleus. It does not appear as though the individual chromosomes anastomose with each other. I consider the resting reticulum as being composed of several independent elementary reticula, formed from the chromosomes as I have described above.

During the early prophases the reticulum becomes more dense and more chromatic in appearance. Each chromosome becomes more condensed and distinct, resembling those found in the reconstruction stages. The vacuoles become fewer, and the chromatic portions larger and closer together. The chromosomes thus condensing are arranged into a ribbon or spirem, which is not, however, continuously chromatic, but consists of the individual condensed chromosomes united serially by less stainable achromatic portions. This ribbon, which is at first broad and reticulate, becomes densely chromatic, and very thin and long, with chromatic bodies, which are apparently chromomeres. The ribbon splits lengthwise, while still very long and spirally coiled in the nuclear cavity. The spindle stages follow the usual descriptions.

Although some authors, as Tellyesniczky and Fick, dispute the individuality of the chromosomes, many investigators maintain that the individual chromosomes persist in a somewhat modified form in the resting reticulum. My results support this latter view. Although I have been unable to trace each chromatic granule throughout the various nuclear changes, I regard them as autonomous bodies. The existence of a regular reticulum, composed of chromatic portions united by linin strands, and the appearance of nuclear regions, which correspond to the reticulated chromosomes, support this view. Since the same chromatic bodies, from which the chromosomes form the reticulum, re-enter the same chromosomes, the chromosomes themselves not only persist as individuals, but are apparently composed of autonomous granules.

---

5. *The Nuclear Phenomena of Ascomycetes in relation to Heredity.* *By* Miss H. C. I. Fraser, *D.Sc.*

In the majority of Ascomycetes investigated fertilisation involves the fusion in pairs of several nuclei. In normal cases one member of each pair is derived from an antheridium, the other from an ascogonium. In various degenerate forms the antheridium is wanting and the ascogonial nuclei fuse one with another, or in the absence of the ascogonium also, vegetative nuclei unite. Fertilisation, whether normal or degenerate, is followed by another fusion of two nuclei in the young ascus.

Recent investigations[1] have shown that these two successive fusions are compensated by two reducing divisions, the sexual fusion by a meiotic reduction such as is associated with fertilisation in other organisms, the fusion in the ascus by the simpler brachymeiotic process.

Brachymeiosis differs from meiosis in several particulars; the most essential seems to be that in meiosis the chromosomes are united two and two to form gemini; whereas brachymeiosis may be accomplished (*Humaria rutilans, Lachnea stercorea*) without visible union of the chromosomes, and even when pairing takes place (*Ascobulus furfuraceous, Humaria granulata*) the opportunity for an interchange of material seems less than in meiosis. It thus appears possible to differentiate between sexual and asexual fusion by a study of the subsequent reduction processes.

The paternal and maternal allelomorphs and also the allelomorphs which are brought together by the asexual fusion in the ascus show very various degrees of association. Sometimes (*Humaria rutilans*, &c.) they do not become paired before the reducing division, sometimes they unite (*Phyllactinia*,[2] *Humaria granulata*, &c.) at an earlier stage. Variations in this respect are not confined to Ascomycetes.

---

6. *The Nucleus of the Yeast Plant. By* Harold Wager, *F.R.S., and* Miss Annie Peniston.

In living yeast cells in healthy condition there is always present a well-marked vacuole containing one or two bright refractive granules which exhibit a brownian movement.

This vacuole, together with a homogeneous, stainable body, the nucleolus, in close contact with it on one side, is the nucleus of the Yeast cell.

The examination of well-stained specimens, under high powers of the microscope with suitable illumination by means of a good substage condenser, shows that there is in contact with the nucleolus and intimately connected with it a more or less well-developed granular chromatin network, which occurs mainly at the periphery of the vacuole.

The nucleolus and nuclear network contain nuclein, as is shown by their reaction towards stains and various reagents, and both contain organic phosphorus and masked iron, as shown by the reactions given by Macallum.

Immediately outside the nucleolus, in close contact with it, and in the cytoplasm immediately adjacent, we often find numerous chromatin granules. These also give the phosphorus and iron reactions.

The nucleolus varies very considerably in its capacity for stains; sometimes so deeply stained that it seems to form with the chromatin granules around it a single irregular stellate-looking mass, at other times so slightly stained as to be almost invisible. At such times we generally find at the periphery of the nucleolus a single deeply-stained granule in close contact with it or embedded in its substance.

The nuclear vacuole exhibits great variation in its capacity for stains. The chromatin granules are sometimes present in large quantity, sometimes almost completely absent. The amount of chromatin appears to vary with the state of metabolic activity of the cell.

The prominence of the nuclear vacuole at certain stages suggests the possibility that it plays an important part in the metabolic activity of the cell, possibly in the elaboration of chromatin.

The cytoplasm often contains bright refractive granules which are visible in the living cell. Some of these are composed of a fatty substance,

[1] Fraser, 1908; Fraser and Welsford, 1908; Fraser and Brooks, 1909

[2] Harper, 1905.

others are similar to the metachromatin granules of Babes and the red granules of Butschli, which are now called volutin granules. They vary very considerably in number at various stages, appear and disappear with remarkable ease, and are associated with active metabolic conditions. They occur either directly in the cytoplasm or in what may be called volutin vacuoles, and from one to three granules, possessing somewhat similar characteristics, are usually found in the nuclear vacuole.

Glycogen is very abundant at certain stages. It is visible in the living cell in the form of clear bright refractive vacuoles or vacuolar spaces.

In the process of bud formation the nucleus divides amitotically into two equal or unequal portions, one of which passes into the daughter cell together with a portion of the network of chromatin. In spore formation the nuclear vacuole and network disappear before the division takes place.

7. *Interim Report on the Structure of Fossil Plants.* See Reports, p. 320.

8. *Report on the Survey of Clare Island.*—See Reports, p. 321.

9. *Interim Report on the Experimental Study of Heredity.* See Reports, p. 319.

SUB-SECTION OF AGRICULTURE.

Chairman.—Major P. G. Craigie, C.B., F.S.S.

THURSDAY, AUGUST 26.

The Chairman delivered the following Address:—

The occupant of this chair, in the great annual convention of the promoters and appliers of science, cannot fail at the outset of a new session to put on record his emphatic endorsement of the claim, so strongly and so reasonably pressed by his distinguished predecessor at Dublin, that distinctively agricultural problems, instead of being regarded as a subsidiary sub-section of any single division of the Association, should be accorded the full dignity and convenience of a 'Section.' Specialised research is to-day one of the governing features of scientific inquiry. It is but fitting, therefore, that those who are trying to equip the agriculturist with all the knowledge which recent speculation and experiment have to offer for the fuller and more economic development of the soil should at least be allotted equal space and sectional rank with the engineer, whose problems are discussed in Section G, or with the schoolmaster, whose educational methods are debated in Section L.

If there were any country in the world where an apology could legitimately be offered for relegating agricultural science to a secondary position, it is certainly not that in which we meet to-day. In this wide Dominion of Canada, in this progressive province of Manitoba, in this great city of Winnipeg, where the agricultural industry must dominate the interests of the people, hardly any subject in the whole range of study can claim a

more paramount degree of attention than the utilisation of the land for the use of man.

This is by no means a matter which can be disposed of as an occasional side-issue in the deliberations of any single Section. If we agriculturists have been tardy in coming to be taught by the scientists, we are in earnest now in the application for instruction that we make. Neither is it to any one science we appeal. Even the stern mathematician or physicist of Section A can teach us something, arithmetical and meteorological, for the right conduct of our business and the wiser forecasting of our plans. The chemists of Section B have, in an infinite variety of tasks, to come to the aid of the farmer, and they have doubtless much to tell of the magic they can promise in the direction of fertilising methods. Section C must be raided for the experts who know the contents of the soil itself and its capacities. Section D may have much to pass on to us concerning the live stock and the insect enemies of our farms. Section E may enlighten us on the world-wide distribution of crops and the new regions awaiting the skill of the husbandman. To Section F we look for warnings as to the economic conditions and barriers which—as we are apt to forget—hedge round our industry, and for the statistics which must govern the varying direction which we give to our enterprise from time to time. The mechanical operations of our calling suggest to us the practical assistance which Section G can surely offer. Nor does even Section H lie wholly remote from the inquiries we may need to make as to the resources of the globe and the wants of diverse communities. The physiology of Section I opens regions of research quite germane to many of our daily studies. Under Section K, as an overlord, we rest to-day assured that if every botanist is not a farmer, every farmer must in a sense be a practical botanist, for ever face to face with the plant and its environment. Perhaps also, in common with all the rest of the world, we may have something to our advantage to hear from the pedagogues of Section L, who may advise our scientific counsellors as to the best form in which even the practical farmer may be taught.

Addressing ourselves, however, to the immediate task in the sub-section allotted to us, I suggest to you to-day that, having regard to the place where we meet, I may, as a proper prelude to your debates, invite you to consider, even if only in the broadest way, what are the leading factors that govern the fluctuations of this our industry of agriculture all the world over, and in new countries in particular. The first factor of all is undoubtedly population—its growth, its rapidly varying local distribution, and its changing and diversified needs. It is for man that crops are raised, whether these crops are to furnish food for direct consumption or for the sustenance of live stock, or whether they furnish us with our clothing, like the wool and the cotton of other lands, or with the materials for shelter, as the great timber crops which your vast forests here may bear. When we know what is the demand at any given place and time, we shall be prepared to give a more exact examination to the means of turning out the effective supply at the right moment and in the right place, be it of wheat, of meat, of fruit, of wool, of flax, of cotton, or of timber.

Sir Horace Plunkett told us last summer that he hoped to find in an Agricultural Section 'some humanised supplement to the separated milk of statistics.' Perhaps he unconsciously reflected in that remark the suspicion that in earlier days the agricultural debates, which, for want of a better place, took place in the Economic and Statistics Section, unduly paraded the bare figures of the position. But I myself confess that, however mortals may shrink from the rigid arbitrament of arithmetic, neither the teaching of the scientist nor the rhetorical advice of the philosopher will lead the agricultural student of the future, even if he have the luxury of a complete Section of his own, to any fertile result, unless he begins by a clear diagnosis

of the facts as they stand, on the one hand as regards population, on the other as regards production. We shall by no means waste time if we try to investigate, with some approach to exactness, what are the areas still available for extended cultivation, and who and where are the consumers of our products, and what are their present and future demands.

Obviously, however, in the limits of an Address like this it is impracticable to make, in any detail, a world survey such as this implies, and it is only the most patent of the changes in the world's populations and their agricultural demands which I can put before you. There was a time when the human family lived in self-contained groups, extracting their requirements from the soil which lay around them. So lately as one hundred years ago there was very little of the international trade in food or other agricultural products such as is familiar to our practice to-day. The nations largely lived on their own territories, and the world has wide sections still where production is limited by local needs. But even a hundred years ago or more perpetual questions were emerging as to the time when men should have multiplied more rapidly than food. The transportation revolutions of the nineteenth century may be almost said to have laid that scare by their aid to the mobility alike of the world's populations and of the world's produce. For the migration of men from dense settlements to open lands on the one hand, and the transport of their produce to the cities of the old world on the other, have simplified, and may simplify still further, the solution. It is all a question of distribution.

If the world holds to-day just twice as many souls (as the best demographic authorities seem to assume) as it did only some two generations back, this growth has been by no means uniform, and the development is governed and provoked by the pressure of population on sustenance. Sometimes, I think, we are apt to forget what Professor Marshall, of Cambridge, has so well laid down, that 'man is the centre of the problem of production as well as that of consumption, and also of that further problem of the relation between the two which goes by the name of distribution and exchange.' Vastly has the latter problem been simplified by the giant strides the second half of last century has seen in annulling distance and in facilitating transport, till all the world bids fair to become a single community. Whether the present distinguished British Ambassador to the United States was right in looking forward to the gradual unification of the type of the world's inhabitants by the diverse processes of ultimate extinction and absorption of inferior races, I think we will agree with him that the spread into new regions of conquering or colonising races has provoked desires for, and made practicable the supply of, far more varied wants than once were even contemplated, or could indeed have been made available, while the producing areas were sundered widely from the consuming centres.

The sixteen hundred million souls this earth of ours now carries are at present by no means evenly spread over its surface, and a population chart reveals the most extraordinary diversity in the density of the people on the soil. More than one-half are on the continent of Asia, and of these a large section are densely clustered in India, China, and Japan. In Europe, where the average density is double that of Asia, and approximately one-fourth of the world's inhabitants are gathered, many portions are nevertheless still far less thickly peopled than the Eastern States just named. Populations, over any considerable areas, exceeding 500 to the square mile, may be found on the world's map not only in parts of the United Kingdom, in Belgium, or in Saxony, but yet again on the Lower Ganges, on the Chinese coast, and even in portions of the narrow valley of the Nile. But the Indian or the Chinaman are not, broadly speaking, to be ranked among the communities of which we are thinking when we concentrate our attention on the increasing transport of breadstuffs or of meat from the New World to

the Old, which has become the prominent feature of the agriculture of our own day, whatever attention may have to be given to the conditions of the Far East at some distant date.

The great movements of agricultural products which have signalised the last half-century are not for the most currents of food supply into Asia, or into Africa, or North America, despite certain limited exceptions which are just beginning to attract attention, as possibly hereafter significant in the case of imports of wheat into Japan or China, of Australian meat into Eastern Asia and South Africa. The Asiatic or the African agriculturist is for the most part content to find the primary necessities of life close at hand. It is mainly Europe, and indeed Western Europe, that calls to-day for the import of breadstuffs or meat or dairy produce. There the growing volume of sea-borne imports has not only materially influenced the agriculture of old settled countries, but at the same time has signalled to the European toiler that space and plenty awaits him oversea, and has stimulated the development of new spheres of cultivation at a rate which the relatively sparse population of the New World, unless largely recruited by immigration, could never accomplish.

I ventured some years ago, from the chair of the Royal Statistical Society, to review the recent changes we have seen in the structure of the world's populations, and urged the greater wisdom of bringing the men to the food rather than the food to the men. The centripetal force which was, in all parts of the earth and not in the oldest countries only, packing more and more together the human family in vast industrial centres, which drew the materials of their handicraft and the food for their maintenance from far distant lands, seemed to my judgment a much less healthy form of development than the older centrifugal impulse which led man to move himself to the newer regions, where the produce was nearer to the mouth of the consumer, and where he could fulfil the oldest obligation of the race to go forth and replenish the earth and subdue it. The vision that meets us here of ample land awaiting man, of possibilities of agricultural production which can only be realised by well-considered and augmented immigration, impresses the visitor from an old and overcrowded country. Before and above all speculations of what transport has done, and may yet do, to carry masses of agricultural produce across the ocean, I must claim, as the better prospect, a steady settlement of these wide acres by a population resting on the soil which this great Dominion offers, and drawing from it, by a more diversified and more general and more wholesome type of farming, a far better, and in the long run a more economic, return than the mere extraction of grain for export can ever promise.

Taking the thirteen States of Western and Central Europe as an example of what I mean, there were added there, in the last seventy years of the nineteenth century, on a comparatively limited surface, something like 100,000,000 new consumers to the 167,000,000 persons previously resident on the 1,700,000 square miles of territory occupied by this group of nations. These numbers, too, take no count of the emigration which has lightened the pressure on the soils of the home lands of Europe. Clearly the maintenance of nearly 70 per cent. more consumers must have meant either a vast development of local agricultural production or a vast demand upon the acreage of the new land of the West, or both. The defective nature of the early statistics obstructs the search one naturally makes into the extent on which these new populations on the old lands have been fed on larger local areas, or from larger yields on non-expansive areas. Adopting, therefore, a much shorter range of view, the lifetime of a single generation has given us 30 per cent. more consumers in Western and Central Europe than were there in 1870, the German element rising apparently by 50 per cent., the Scandinavian, Belgian, and Dutch group of small nationalities by 44 per cent., and the United Kingdom by 40 per cent. in this interval, while

these developments were of course reduced in their effect on the total by the slower growth of the South-Western nations and the nearly stationary condition of France.

No larger areas, but rather smaller ones, of the chief food grains are apparent in Great Britain or Scandinavia or North-Western Europe. The German areas of wheat and rye show practically little change, and although, if the Hungarian areas are larger in the centre of Europe, the general movement is not upward in respect of food-producing area. Even in live-stock the numbers scarcely keep pace with population, for although the herds and the swine of Western and Central Europe have risen by nearly a fourth in the one case and three-fifths in the other, the sheep, except in Great Britain, are much fewer now.

On the average of the first quinquennium of the present century the home production of wheat represented only about 20 per cent. of the consumption in the United Kingdom or in Holland, 23 per cent. (apparently) in Belgium, 64 per cent. in Germany, and perhaps 80 per cent. in Italy; and the imported grain to fill the deficits was considerably over 400,000,000 bushels. Nearly half of this came, of course, from Eastern Europe, and particularly Russia. Such a mass of produce would require 20,000,000 acres elsewhere, even if the exporters could raise it, as most have certainly *not* done, at twenty bushels per acre, and nearly double that area if the yield was only that of some of our largest exporters to-day.

The actual reductions of area in Western Europe are not in the aggregate extensive, although Belgium has seen her grain area shrink from 30 to 25 per cent. of her total surface, France from 28 to 25·5 per cent., and the United Kingdom from 12 to 10 per cent. The grain-growing capacity of European States varies greatly, and it would be interesting, were the data everywhere available, to see how far we have distinct evidence of an appreciable if not any great advance in the yields extracted from the non-expanding areas under the more recent conditions of scientific knowledge. Nowhere is so large a share of the total surface under grain as in Roumania, an Eastern European State and not inconsiderable wheat exporter, and there, at all events, the total grain acreage developed between 1886 and 1906 by nearly 25 per cent., and the surface under wheat by 72 per cent. The yield there, according to some official reports, was something over fifteen bushels per acre in the five years before 1890, and in those ending 1906 it was over nineteen bushels—the latest year nearly touching twenty-three bushels; the barley yields of the same State rising from an average in the former quinquennium of thirteen bushels to over nineteen bushels in the latter.

In Hungary, another European grain exporter, the wheat acreage has been materially developed, rising from over 7,000,000 acres to 9,500,000 in twenty years to 1906, and but slightly receding since, while the yields are also materially greater.

France, with a drop in wheat acreage of 1,000,000 out of 17,000,000 acres, has between 1884 and 1908 raised the average of her production on a five years' mean from 17·8 bushels to 20·2 bushels, and thus turned out somewhat more produce from a lessened surface.

Germany, on a constant but much smaller wheat area of 4,700,000 acres, with a quinquennial average yield of 20·3 bushels, would seem to have raised this to 27·9 in 1899-1903, touching a still higher level in more recent seasons, when 30 bushels were apparently approached, although some changes in her statistical methods of inquiry may slightly reduce this comparison.

Some effort to feed new mouths from old acres has thus indeed been made. Nevertheless, without disregarding altogether the qualifications which a careful statistician would deem it his duty to admit, one may broadly say Western Europe looks mainly for the growing needs of her consumers to the

still exporting States of Eastern Europe, to the New World regions of North and South America, and in a minor degree to Australasia.

Before we quit our session here in Winnipeg we may expect to learn something of scientific interest and of economic guidance respecting the response of Canada to the Old World's call. But it is not for grain alone that densely peopled countries turn to the new fields of the West. Probably the geographical conditions of our place of assembly this year will not lead us at all closely into discussion on the variations in the sources and fluctuations in the volume of the wool supply, or that of cotton, but the possible development of livestock on the territories of newly settled countries may be expected to come well within our purview, and afford us lessons in the development of the export trade in meat and dairy products, and the relation of the Canadian to the surplus of other States. The Royal Statistical Society of London had a paper this summer by an old colleague of mine, Mr. R. H. Hooker, which, although primarily devoted to the supply of Great Britain herself, and the price of meat in her markets, has a world-wide view of what is going on all around us in the conditions of production and of transport in a commodity as important to human life as wheat itself.

Fully a quarter of a century has gone by since, on a former visit to Canadian soil at Montreal in 1884, I raised a debate on this subject of the production and consumption of meat, and the various conditions of its transport. The twenty-five years that have passed since then have not rendered that particular topic a less important one for the consumers of old countries or the farmers of new, but ever-varying factors are presented by the opening of new territories to exploitation and the denser massing of accumulated populations with growing needs, and increasing preference for the most concentrated form of aliment. Among the most recent factors to be remembered as influencing one side of the meat trade future are the admissions of qualified experts in the United States as to the degree in which the growth of population there was beginning to trench upon the meat surplus of that Republic. On the other hand, the producer will not fail to bear in mind the rapidly advancing importance of partially developed areas and the great advantage of the more economic forms of dead-meat transport now adopted in South America, and will weigh against these the degree in which the herds of the vast prairies of North-Western Canada may be further utilised when questions of handling economically the resultant meat supply may be effectively elaborated.

To-day, however, and here especially, one cannot but be reminded that in whatever direction we look for the aid of science to stimulate the development of Canadian resources, or to help the producers now in these provinces in measuring the probabilities that lie before them, or to summon eager emigrants to the land you have to offer them, there is an intense and ever-engrossing interest in the present and the future of wheat. Alike, therefore, to the statistician and economist on the one hand, and to the experimentalist and investigator on the other, we turn to ask what advice they can give to the farmer of a new country with an area so vast as the North-West of Canada presents, whether and how far and at what rate, with profit to himself and with benefit to the bread consumer across the ocean, he can push the extension of the well-nigh eight million acres of wheat land which the Dominion claims to show her visitors in 1909.

The problem, important as it is to this particular region where we are met, cannot, however, rightly be treated as a purely Canadian question. It is a problem of world-wide interest and of great magnitude and more complexity than has been sometimes recognised, for it is none other than the issue of the race between population and production so far as at least one primary essential of human diet—bread—is concerned.

Within a year of the last visit to this Dominion of the British Association the question was raised by no less an authority than the then President

of that body at the Bristol meeting of 1898, whether the possible wheatfields of the globe possessed a potential capacity of expansion sufficient to meet the hypothetical needs of the bread-eaters of even one generation ahead; whether, in fact, a dearth of wheat supply was not already within sight, and by 1931 would be upon us. The suggestion that the wheat-producing soil of the world was already becoming unequal to the strain put upon it by the multiplication of men was not unnaturally met by a vigorous criticism. The mere suspicion that some day, however, there would not be land enough to go round, that famine could be averted only by the beneficial magic of the chemist, is too vital a possibility—even if some of us do not place the date so near or rely so fully on some of the computations made—not to command a very careful examination of the remedy propounded, the promise of the artificial production of nitrate in such a volume and at such a price as would raise the average of the world's production from 12·7 to 20, if not even to 30 bushels of wheat per acre.

The fixation of nitrogen, not as a dream but as a certainty, was, it will be remembered, claimed by Sir William Crookes as the condition on which the great Caucasian race was to retain its prominence in the world, and avoid being squeezed out of existence by races to whom wheaten bread is not the 'staff of life.'

Personally, I confess I am not so pessimistic as to the surface still available for wheat-growing even without this aid. If we grant that the so-called contributory areas, at a date two or three years before the close of last century, were just what was then stated, that the bread-eating population of that date was rightly guessed at 516,500,000—a much more difficult certainty to reach in the manner adopted by the American statistician whose figures were adopted—and that both the growth of population and of 'unit consumption' would proceed exactly in the ratio suggested, it may legitimately be asked, does it nevertheless follow that no such increment of area can be looked for as would satisfy the larger mass of consumers calculated for as likely to be dependent upon wheat in 1911 or 1931 on the scale here laid down?

I should not, in any statistical investigation into these questions, be contented to assume the probability of the exact continuance of previous ratios in the rate of production, or that of individual consumption over such periods, and my experience of very big averages makes me shy of adopting a simple mean of such wide diversities as correctly representing the head-rate consumption of wheat. These are points which might be more fittingly debated elsewhere. I want to narrow the issue now to the actual and more recent course of the wheat-growing surface; for it seems to me that the lesson of such figures as we have in the past, and as those of Mr. Wood Davis's tables, is rather one of irregular than of arrested extension. The periodical opening up of new areas, very often in advance of consumptive requirements of the time, would seem almost invariably to be followed by a pause while prices recover from the over-supply, and that again by new developments and exploitation in new directions, or by better methods on the areas made tributary to the wants of the ever-increasing men.

We may admit that the course of the wheat acreage from 1870 to 1884 and thence onward to 1898 showed—first, a material advance outstripping that of population, then an admitted and serious check, with a subsequent advance, although one below that of the bread consumers of the world.

Let me ask, however, if a later view of the wheat area at the disposal of the world's consumers is not well qualified materially to diminish, if not to dissipate, the 'cosmic scare' which, no doubt contrary to the real design of the distinguished chemist who followed Mr. Davis's estimates, was induced by the figures of 1898. My own comparison of the later growth of acreage covers only the decade from 1897 to 1907, or as nearly to these years as figures permit, and in the form I originally designed it

might bring into view something under 230,000,000 acres as the world's present extent of wheat-field. But, to place matters on a more comparative level, I am willing to omit the large Indian totals and some few of the distant regions which, partly on account of the somewhat uncertain identity of the areas they include at different dates, and partly on account of their relatively small contribution to the bread of the Western world, do not find a place in the estimates with which I am now making a comparison. For the leading groups of other areas the figures stand in millions of acres to a single decimal:—

Groups	1897	1907	Increase in 10 years
Russian Empire	46·6	59·5	12·9
United States	39·5	45·2	5·7
Three chief European Wheat States	37·6	39·8	2·2
The Rest of Europe . . .	20·8	21·4	·6
Argentina and Uruguay . . .	6·7	15·0	8·3
Canada	3·0	6·6	3·6
Australasia	5·0	6·0	1·0
Total	159·2	193·5	34·3

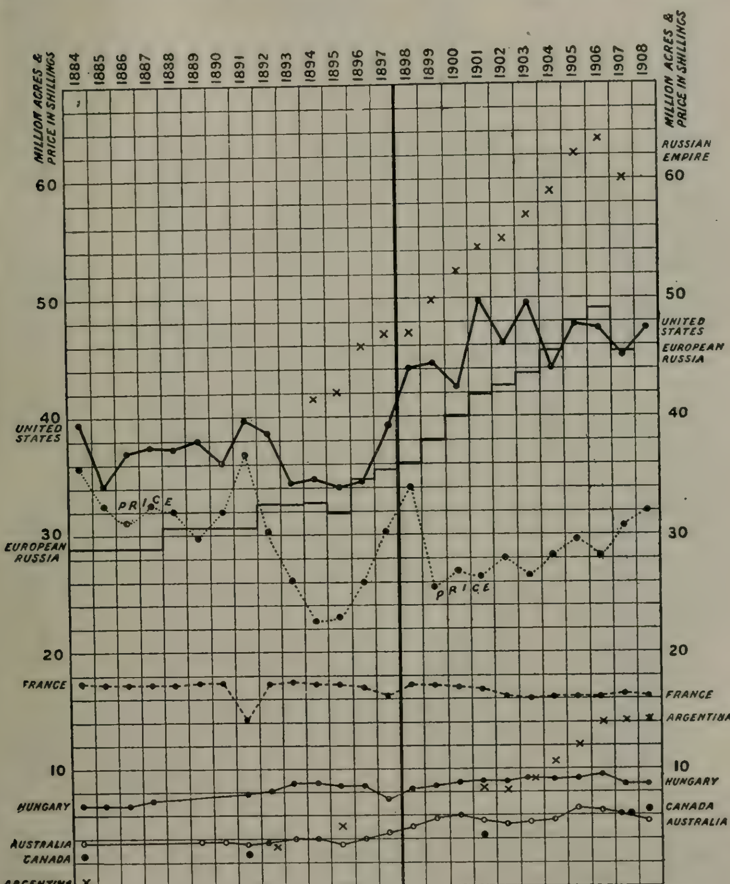
Now, whatever be the estimated increase in wheat-eating population between these two dates, it cannot in the aggregate be $21\frac{1}{2}$ per cent., as is the growth of the wheat surface in these States. Nor will the result be materially affected if allowance were to be made for the three or four million acres represented by the exports of unnamed States in this table, or even by the inclusion of any minor units of wheat-growing, such as Portugal, or Greece, or Switzerland, for which Mr. Wood Davis estimated from sources not recognised in our official statistics, their totals being well under a single million acres, and the variation, if any, probably insignificant.

If, therefore, the growth of men outstripped the growth of wheat, as we have been warned was the case between 1884 and 1897, the growth of wheatfields has been well over the rate of population increase since that exceptional period, just as it was in the still earlier period between 1871 and 1884. Nor is the check to the rye acreage and its decline by 4 per cent., which seemed to have happened concurrently with the wheat check between 1884-1897, continuing; for that, in the aggregate, seems to have returned to, though it has not perhaps much exceeded, the older level.

Comparisons at single terminal points have always a danger which may be avoided by examining more carefully the leading facts year by year. On the diagram which I introduce here I have tried, therefore, roughly to sketch the curves which indicate the growth of wheat acreage, both before and since 1898, in Russia, the United States, Argentina, Australia, and Canada, as typical of the exporting centres, while the acreage in France and Hungary has been added for comparison. The effect is, I think, to bring out the very much greater extension which has been going on during the last decade than could well have been looked for on the basis of the 1884-97 figures.

For the Russian Empire as a whole data are available only since 1895, but I have shown by a separate and steadily mounting line the wheat area of the fifty governments of European Russia, which are comparative for the entire period, and the latter are quite sufficient to establish my conclusion. There is, too, a suggestiveness about the course of prices (in shillings per quarter) in England, the chief recipient of wheat exports, which I have traced by a separate curve across this diagram. This may

perhaps aid those who are disposed to make a closer study of the figures. That study may not improbably suggest that in the very latest years—for I have carried the diagram to 1908 where I can—we may be once again nearing another check, or temporary halt, in the course of wheat extension, such as that which puzzled inquirers more than ten years ago, but which proved only a pause in the task of finding all the bread the consumers



wanted under the stimulus of better prices. The further leap of prices in 1909 to beyond the 40*s*. limit in England may effectively encourage extension.

The exceptional arrest of wheat-growing in the United States between the years 1880-1896, when—if we may accept the official statistics as actually representing fact—the rapid rise, which actually doubled the wheat acreage between 1870 to 1880, stopped altogether, was, I believe, the preponderating factor which suggested a general halt in wheat-growing. It should therefore be looked at more closely, and to get rid of the danger of attaching too much

Acreage of Wheat in million acres.

Year	Russian Empire	Of which in European Russia	United States	France	Hungary	Argentina	Australasia	Canada	Of which in N.-W.
1884	—	28·9	39·5	17·4	6·8	0·6	3·8	2·4	—
1885	—	—	34·2	17·2	6·8	—	—	—	—
1886	—	—	36·8	17·2	6·8	—	—	—	—
1887	—	—	37·6	17·2	7·3	—	—	—	—
1888	—	30·6	37·3	17·2	—	—	—	—	—
1889	—	—	38·1	17·4	—	—	3·8	—	—
1890	—	—	36·1	17·4	—	—	3·7	—	—
1891	—	—	39·9	14·2	7·9	—	3·4	2·7	—
1892	—	32·6	38·6	17·3	8·1	3·3	3·7	—	—
1893	—	32·4	34·4	17·5	8·6	—	4·0	—	—
1894	41·6	32·9	34·9	17·3	8·5	—	4·0	—	—
1895	42·2	31·9	34·0	17·3	8·3	5·1	3·6	—	—
1896	45·9	34·8	34·6	17·0	8·3	—	4·0	—	—
1897	46·7	35·6	38·5	16·3	7·4	—	4·5	—	—
1898	47·0	36·0	44·1	17·2	8·2	—	5·0	—	—
1899	49·7	38·0	44·6	17·1	8·4	—	5·9	—	—
1900	52·3	40·0	42·5	17·0	8·8	—	6·0	—	2·5
1901	54·3	41·9	49·9	16·8	8·9	8·3	5·6	4·2	—
1902	55·1	42·6	46·2	16·2	8·9	8·1	5·2	—	—
1903	57·2	43·8	49·5	16·0	9·2	9·1	5·5	—	—
1904	59·2	45·6	44·1	16·1	9·1	10·7	5·8	—	—
1905	62·2	48·1	47·9	16·1	9·2	12·1	6·5	—	3·9
1906	63·6	49·0	47·3	16·1	9·5	14·0	6·3	—	5·1
1907	60·0	45·5	45·2	16·3	8·6	14·1	6·1	6·1	—
1908	—	—	47·6	16·1	8·5	14·2	5·6	6·6	5·6

importance to the data of single years, the quinquennial average movement in the States over the whole of the last forty years may be summarised as under:—

Five-year Periods	Acreage in U.S.A.	Distinctive Wheat Acreage Levels
	acres	
1868–72	19,500,000	Extending rapidly up to 1880
1873–77	25,500,000	
1878–82	35,500,000	Nearly stationary from 1880 to 1896
1883–87	37,000,000	
1888–92	38,000,000	
1893–97	35,500,000	Again extending to maxima reached in 1901 and 1903, with a later slight decline in the latest years
1898–1902	45,500,000	
1903–1907	46,800,000	

Population in the States has, of course, augmented steadily all over the forty years, from 37,000,000 to 86,000,000, yet all through the stationary years, as well as those of advancing acreage, exports of wheat and flour continued—as much as a third of the crop being shipped abroad in some years—and the transfer of the wheat lands north-westward in the States was doubtless the striking feature of the recovery. Rightly to understand the revolution in the wheat-growing of certain States of the Union would require a treatise for which time could not be given here.

Let me, however, recur again to the general position. In the table already given for the past decade the latest increase to be accounted for is 34,000,000 acres. I ask you to note that the Russian quota forms more than a third of the whole. Now it was Russia that was in a very special degree the subject of unfavourable remark in the wheat problem controversy of ten years ago.

She was spoken of, I remember, as having reduced her consumption of bread by 14 per cent., and only by this means continuing her exports in defiance of her true needs, and contributing to the rest of the world therefore a merely provisional and precarious excess. I am not aware how the calculation here alluded to had been arrived at, nor have statisticians perhaps a very robust faith in the estimated numbers of the Russian population before the great census of 1897, but the subsequent history of her apparent wheat surplus is interesting.

The exports of wheat from Russia, which we were warned could not continue, and which had doubtless been unusually large between 1893 and 1898, shrank for three years after that date as if they would realise the prophecy which would relegate Russia from the ranks of exporters to the task of feeding her own population. But that mysterious empire has since then resumed her large supplies, and from 1902 to 1906 the exports ranged higher than before. Although forming only 24 per cent. of her estimated wheat crop, Russia's exports averaged 141,000,000 bushels over the first five years of this century, against 104,000,000 bushels over the whole preceding fifteen years. Quite lately we seem to see some restriction, but the history of the trade forbids a confident opinion that she has reached the end of her contributions to other lands.

So far as the areas under wheat are recorded, the Russian agriculturist keeps on extending his industry, and, low as the yields may frequently be, they are tending upward under, it may be presumed, some reform of the very primitive conditions of production. Within the fifty governments of European Russia alone, and omitting the Polish or Caucasian figures, which do not go so far back, the average area of 29,000,000 acres only in the 'eighties became 40,000,000 at the close of the century, rising to a maximum of 49,000,000 acres in 1906, a point from which a decline was shown in 1907 to 45,600,000 acres. This, however, even taking the latest and lower figure, is an advance of 10,000,000 acres in the last decade, or nearly 30 per cent.—surely considerably in advance of even the Russian growth of population, great as that is.

It has, I think, not been sufficiently realised that in the two decades stretching from 1887 to 1906, European Russia has added 1,000,000 acres of wheat per annum. This is not only a 70 per cent. advance in twenty years, but it is double the absolute area of 10,000,000 acres which the United States added in this interval. From such official estimates as are furnished, the total produce of these fifty governments, where alone the figures are continuous, increased in a still higher ratio. The average production, which did not exceed 180,000,000 bushels in the five years before 1879, or 226,000,000 bushels in the quinquennium ending 1889, reached what appears to have been a maximum in 1904, and was averaged at 415,000,000 bushels for the whole five years' period then ending. If the later years are again at a lower level, they represent very nearly double the produce before 1879. The yield per acre, which stood below eight bushels to the acre between 1883 and 1892, averaged nine bushels over the next ten years, and has been 10·9, 10·4, and 11·4 bushels respectively in the three seasons ending 1904. In the southwestern region, where the yield was just over eleven bushels in the decade ending 1892, it seems to have averaged fifteen in the ten years ending 1902, while over eighteen and nineteen bushels were reported in 1903-1904.

These figures omit the Polish, Caucasian, and Asiatic districts, for which a much smaller retrospect is possible. The acreage in Poland is small—little over a million—and nearly constant in extent. But the wheat of Northern Caucasia, first accounted for in 1894, has risen from 5,600,000 acres to 8,300,000 in 1906, and the Siberian totals, after increasing, apparently but slightly, from 3,400,000 acres in 1895 to 4,800,000 acres at the close of the century, do not seem much to exceed 5,000,000 acres now. Russian wheat production does not therefore seem a wholly arrested process.

I own I was hardly prepared for this old nation's progress in wheat-growing, and I have no doubt that I shall be told that Russia has been exchanging one form of bread corn for another; in particular, that dependence on rye has decreased as production of wheat has grown. There is some truth undoubtedly in this, for the comparatively stationary character of the rye area indicates that the Russian people, increasing as they are and continuing still an export of rye to Germany and elsewhere, may themselves eat somewhat more wheat and rather less rye, and it is true also that a fluctuating record has attended the surface under the coarser and larger cereal crop. Its 'low-water' point—61,900,000 acres—occurs in 1893, while its present figure is 66,000,000 acres. Relatively, therefore, while the rye shows no progress such as wheat, it cannot be said that the rye area has been utilised for the more valuable cereal, and the fact remains that there is more rye grown to-day, even in European Russia, than at any date since the last decade of last century began. Relatively to population, the available data show, the aggregate crops of wheat and rye together, in Russia as a whole, are materially greater than before.

Inquiry shows that the wheat extension in Russia has been made possible by an actual addition to the arable land, and not by deduction from other crops. A recent investigation quoted by a competent American authority informs us that some 23,000,000 acres of new arable land has been accounted for between 1881 and 1904, and, moreover, that a greater surface of this nominally arable area is now actually under cultivation than at the earlier date. These figures stand:—

Year	Total Arable Land	Under Crop	Wheat	Rye
	acres	acres	acres	acres
1881	288,000,000	174,600,000	28,900,000	64,600,000
1904	310,700,000	205,900,000	45,600,000	65,600,000

It will be noted that this inquiry ends a year or two since, but had it been continued to 1906 the comparison would have been accentuated, and, as it stands, the additional area cropped in one way or another exceeds 31,000,000 acres.

In Mr. Wood Davis's later memorandum he combats the idea that the expected wheat crops from four relatively new areas of production—Siberia, Argentina, Australasia, and Canada—would meet the shortage he found threatened by his estimate. Not unnaturally he regarded an 8,100,000 addition of acres in these four regions in fifteen years as a very insufficient and unpromising quota to feed over ten times that number of new bread-eaters on the globe between 1883-4 and 1898-9.

Assuming he rightly gave the increment of wheat between these dates as under, if I add to his table the latest data that I have, these new and gradually opening areas will show a rate of progress much greater in the nine succeeding years than before, even if there was no further increase in Siberia; for as to the areas to be included there I am certain. The figures I give in millions of acres:—

—	1883–84	1898–99	Fifteen years increase	1907–08	Nine years increase
Siberia . .	2·0	3·3	1·3	3·3	—
Argentina . .	1·4	6·1	4·7	14·2	8·1
Australasia .	3·2	4·5	1·3	5·6	1·1
Canada . .	2·4	3·2	·8	6·6	3·4
Total .	9·0	17·1	8·1	29·7	12·6

In the forecasts offered ten years ago Argentina as a wheat-grower was given a dozen years from 1898 to reach a possible acreage of 12,000,000 acres. She has reached that figure and passed it in less than a decade, and later current official estimates seem to concede to that region a close approximation to 15,000,000 acres to-day. As the actual pace here has bettered so considerably that prophesied, one may legitimately question the further limitations which allowed to Argentina no prospect of ever reaching a wheat area of 30,000,000 acres at any time. That these prophecies by no means coincide with later and probably quite similarly vague forecasts in the other direction goes without saying. In a recent official publication by the U.S.A. Government containing the report of an expert on the resources of Argentina and her farming methods, the competitive prospects of the great grain-exporting Republic of the South were scarcely so lightly treated. For my own part I rather agree with an officer of the Argentine Government there quoted (Señor Tidblom), who candidly admits that it was impossible with any accuracy to forecast the ultimate wheat area of Argentina, although I observe he adds that there were 'more than 80,000,000 acres in the Republic that could be *immediately* devoted to successful wheat-farming if we had the farmers to do it.' I have seen, though I could not accept, even more sanguine estimates in other quarters, which, with a yield of only ten bushels per acre, promised a crop of 1,238,000,000 bushels at some future date, and would involve an area of wheat land approaching 124,000,000 acres.

No one, I think, can note the strides which Argentina has taken in rapidly augmenting her wheat areas and exports, and that concurrently with the commanding place she is assuming as a meat rearer and exporter to the older peoples of Europe, without some recognition that a great future is possible. On the other hand, apart from climatic conditions, the future must be largely governed by the factor of population; and the nature of the Italian immigrants, their mode of culture, their non-intention in many instances to remain and own the land or identify themselves with the country—preferring to exploit one farm after another and reside on them until they make a small competence wherewith to return to Europe—are all reasons against the extremely favourable prospects which I have here adverted to.

Small relatively to the great extent of surface included in the Commonwealth of Australia is the proportion under wheat, but the Commonwealth is none the less as a rule an exporter. A little more than thirty years ago only about 1,400,000 acres were grown. This seems to have been a good deal more than doubled in the five years 1876-81, when a much smaller rate of increase followed for fifteen years—a check apparently reflecting the same tendency to arrest which we have seen so typically illustrated in the United States. Again, after 1896, just as in the great Western Republic, wheat-growing became again in favour, and the rapid spurt which followed brought the Commonwealth total to 5,700,000 acres as the century closed. Thereafter the rate of growth seemed checked anew, and after passing a maximum of just under 6,300,000 acres, it stands to-day under 6,000,000 acres. Twice during the last twenty years has Australia shown on balance a net importation of wheat, but from 1903 to 1907 the quantity exported has averaged 36,000,000 bushels, and it is not without interest to observe that the Australian exports of the present century have not all been consumed in Britain—South Africa, the western coasts of South America, and even some parts of India sharing in the surplus product of the Antipodean Continent.

The conditions and the future of Australian wheat have been quite recently dealt with in an interesting paper by Mr. A. E. Humphreys, read before the Society of Arts in London. It is here pointed out that the soils on which it is grown are rich in assimilable nitrogen, requiring little

manurial expenditure in that direction, but poor in their percentage of phosphoric acid, while the climatic conditions as regards moisture have proved remarkably difficult. Efforts have been made, and apparently, if recent experiences be confirmed, with success, to breed new varieties of the wheat plant adapted to the peculiar climatic conditions of Australia and likely to increase the low average yields hitherto obtained. It is obvious that under Australian conditions the breeding of varieties of the wheat plant which will thrive on a low rainfall would make all the difference to Australia as a source of wheat exports. From 1902-1907 the Australian average yield was only half that of Manitoba, or nine bushels per acre; but this included one year of disastrous drought (1902-1903), wherein the Commonwealth average fell below two and a half bushels to the acre. In New South Wales and Victoria, wherein more than half the acreage lay, it was even below this, according to the official figures. Such instances offer the strongest evidence that could be offered of the extreme variability of Australian conditions, and make one almost hesitate to quote Mr. Humphreys' own cheerful estimate that in the State of New South Wales alone, wherein nearly a third of the Australian acreage is found to-day, or 1,886,000 acres, there was a possible area of good wheat land of nearly ten times this, or 18,000,000 acres.

To the last I have left another sphere of wheat extension, and one that will be most of all familiar to my audience. Yet here again the forecast of the Canadian future made in 1898 was surely unduly pessimistic. The opinion then quoted by Sir William Crookes as that of trustworthy authorities assigned to the Dominion a bare total of 6,000,000 acres under wheat as all that could be expected to be reached within a dozen years. That period has not yet fully come, but I observe that by December 31, 1908, the official figures show an acreage as reached within the decade which exceeds by 10 per cent. the maximum allotted to 1910. If I were to add the figure now ascertained for the 1909 crop, a total of 7,750,000 acres is now reckoned upon, so that here again the forecast has been outstripped. The further proposal to estimate the maximum of the Canadian potential capacity for wheat production by 1923 at no more than 12,000,000 acres will therefore, I imagine, meet severe critics in Winnipeg to-day.

I greatly wish that our contribution to the knowledge of the economic future of Canadian development may be, as the result of discussions here, some approach to an agreement to avoid all exaggeration on the one hand or on the other in these forecasts of future wheat-growing in the North-West; but I am very conscious of the risk of all far-reaching prophecy in a problem where the more or less uncertain growth of the immigrant population plays as great a part as the soil or the climate.

Sir William Crookes, in endorsing the most modest estimates of the capacity of this region, mentions that he had before him calculations which, I think most of us will agree, were, to say the least, exaggerated in an opposite direction, attributing to Canada 500,000,000 acres of profitably utilisable wheat land. Against such inflated prophecies he argued that the whole area employed in both temperate zones of the world for growing all the staple food-crops was not more than 580,000,000 acres, and that in no country had more than nine per cent. of the area been devoted to wheat culture. But error of estimate in one direction or another is quite inevitable when the available data on which to form a conclusion are so scanty. Replying later to journalistic criticism, Sir William, it must be remembered, acknowledged the undoubted fertility of portions of the North-West provinces; but, basing the conclusion on official meteorological statistics and on supplementary data supplied by Mr. Wood Davis as to the July and August temperatures of these regions, he suggested that 'from one-half to one-third only' of Manitoba—the south-west portion already fully occupied—was adapted to wheat. It was doubtless in the light of these

climatic records that he inclined to regard 200,000 square miles of the whole 300,000 square miles comprising Assiniboia, Alberta, and Saskatchewan, as these regions were then defined, as lying 'outside the districts of profitable wheat-growing,' while even of the remainder it was apparently suggested that it would take thirty years from 1898 to place as much as 18,000,000 acres *under all grain crops.* Can we here to-day, with another ten years' experience, reach a somewhat greater accuracy in this search into the possibilities before us?

As illustrating the remarkable discordance of view hitherto existing, it is well to have before us, as a starting point for debate, some specimens of later but still most widely varying estimates of the capabilities of this country. These I quote from the cautious report rendered by Professor Mavor to the British Board of Trade in 1904, midway through the decade now closing. More or less speculative as it is fully acknowledged all estimates must be which purport to define the area 'physically or economically susceptible of wheat production,' that painstaking investigator set aside, as of little value, hypothetical curves setting forth the 'northern limit of cereal production,' reliable data for which 'were not forthcoming, and if they were they would be constantly changing.' After enumerating under fourteen different heads and sub-heads a formidable list of distinct but materially qualifying 'conditions' or factors covering questions of soil, of temperature, and meteorology, of moisture, sunshine, and acclimatisation of the plant, Professor Mavor suggests that, broadly speaking, the cleavage of the areas of different fertility runs obliquely from south-east to north-west through the great quadrilateral of the Canadian North-West. Alike in the north-eastern and in the south-western angle the conditions seemed to him more or less unfavourable. The south-eastern and north-western corners and the belt connecting them, however, presented relatively favourable conditions; an exception qualifying this sub-division was, however, suggested in the extreme north-west.

The vagueness of the statistical basis on which any numerical estimate of future wheat areas must rest cannot better be shown than by briefly referring to the results of five independent estimates which are quoted in this report. For the details of these estimates it is necessary to refer any student of the report to the analysis of each, differing as they do materially in their methods and in the classification of the areas comprised within the Manitoba, Assiniboia, Saskatchewan, and Alberta of that date. As regards the total area for settlement and for annual wheat-growing respectively, the first three of these estimates varied in placing the surface fit for settlement or susceptible of cultivation as low as 92,000,000 acres, and as high as 171,000,000, the annual surface available for wheat in these districts ranging from 13,750,000 acres to 42,750,000 acres, and the resultant possible produce from 254,000,000 bushels to 812,000,000 bushels.

It should be added, to make these figures clear, that all the estimators quoted assume as a condition precedent to their accomplishment such an influx of population and settlement of the country as would be adequate to secure the cultivation of the hypothetical cultivable area.

With Professor Mavor, we may think that both the lower estimates are over-cautious and the third perhaps over-sanguine, while most properly he reminds us that beyond the physical capacity of any region, the question of economic advantage remains to be solved, under what may be conditions prevalent at a distant time, what effect a rise of price might have, and whether the farmers of the future would devote so much of their land as is here suggested, and so much of their working capital, to wheat alone. I ought to add that a fourth estimate referred to in the report takes the graphic form of a map, distinguishing the suggested area where the wheat crop is certain, where less certainty exists from the effect of summer frosts, and where, again, the crop is uncertain from insufficient moisture. Yet

another estimate was quoted as made in 1892, but endorsed as not overstating possibilities of the future in July 1904, and this classified somewhat more than half of the land of Manitoba as 'land suitable for farming,' or 23,000,000 acres, allotting to the rest of the North-West 52,000,000 acres more, or in all 75,000,000 acres. The same estimator, forecasting the results for 1912 (or three years from the present time), allotted to Manitoba a probable wheat production of 168,340,000 bushels, and to Alberta, Assiniboia, and Saskatchewan 181,600,000 bushels. This crop of 350,000,000 bushels of wheat was in addition to an estimate of a further 200,000,000 bushels of oats and 50,000,000 bushels of barley. I have little hesitation in concluding, with Professor Mavor, that such widely divergent results, arrived at, as we are told, by competent estimators, illustrated the impossibility at the time of that report of setting out precise limits of cultivation in a region in which so much has yet to be done. To-day I would ask, Has the lapse of another quinquennium, full of interesting movements in both the population and the crops of the North-West, enabled us to reach any greater certainty? If so, the opportunity of this meeting affords an occasion to submit the conclusions, optimistic or pessimistic, practical or theoretical, economic or scientific, to the test of friendly and thorough discussion.

It is a relief to turn from the perplexing variety of these speculations as to the future to the relatively more solid ground afforded by the actual records of wheat extension here. If the progress of the past, and here once again more especially of the very latest decade, is to govern the prospect of the years to come, the wheat area of Canada must still possess a great expansive power.

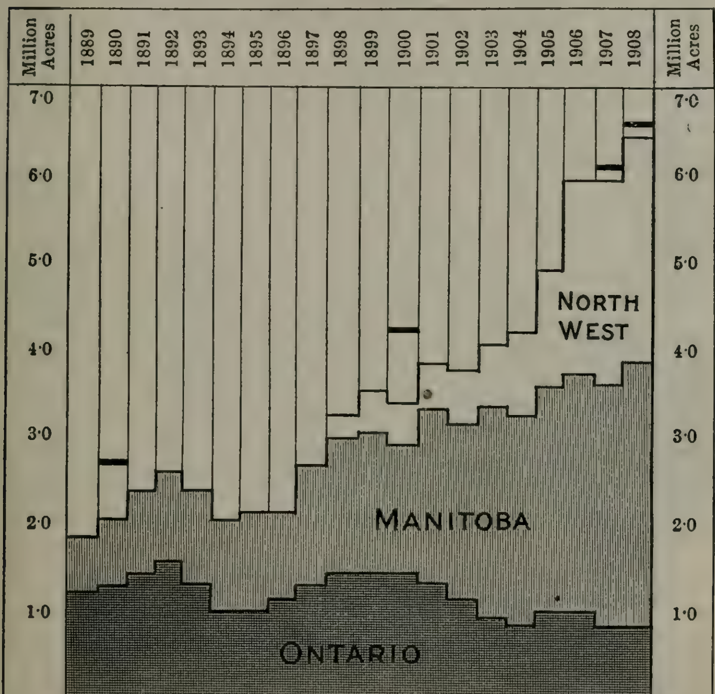
There are defects of continuous statistics showing from year to year the total acreage of the Dominion, although the recent good work of the Census and Statistics Office promises that this will henceforth be remedied. But outside of the three great wheat-growing sections—Ontario, Manitoba, and the North-West—the surface under this cereal is not material. By the latest figures available the four Eastern Provinces do not now grow 170,000 acres collectively, while the small surface in British Columbia, not appearing in the last general Bulletin, was only 15,000 acres at the last census. In the roughly sketched diagram I insert here, therefore, the course of wheat-growing on 97 per cent. of the 6,611,000 acres accounted for in 1908 may be conveniently, if only approximately, traced.

The decline in Ontario, where, as in other older settlements, wheat-growing shrinks as more diversified forms of agriculture evolve, is much more than compensated for when the acreage of Manitoba, and in later years the rest of the North-West, is superadded, as in the columns of this diagram, and the rapidity of the recent extension, which—had the 1909 figures reached my hands sooner would have carried the total area far beyond the seven million limit—testifies to the energy in the task of bread-raising which this hopeful section of the British Empire displays.[1]

But whatever determinations we can reach on the hypothetical questions here propounded, whether we may regard the greater rate of wheat-field extension in the world at large, which has marked the last decade, as disposing of immediate alarm for the bread supply of the next generation, or whether we find in the recent whisper of augmenting prices corroboration of the gain of population on subsistence, it is clear that our statistical records require a further development and a much improved continuity,

[1] Were the preliminary estimates for 1909 taken into account, the total acreage would have been given as 7,750,000 acres—a rise of 1,139,000 acres in the latest twelve months. This is indeed the net result, for the West has added 1,402,000 acres—of which 1,289,000 were in Saskatchewan and 113,000 in Alberta—while there are declines in the East and in Ontario of an almost exact equivalent of the last-quoted figure, or 114,000 acres, and likewise a reduction of as much as 149,000 acres in Manitoba since 1908.

especially in the new regions of the wheat supply of the future. Nor yet, again, can we dispense with the urgent lesson that science has much to teach us in making more use than we do of the areas acknowledged to be under more or less rudimentary cultivation. If Sir William Crookes was right in adopting the American statistician's average of 12·7 bushels per acre as the mean of the recognisable wheat-fields of the world, the prospect of the extra seven bushels he sought as immediately desirable will make us eager to learn the very latest triumphs of the laboratory in winning for the soil a freer measure of the nitrogen of the air. Even here in Manitoba, where a much higher yield seems on the average to be main-



tained under existing conditions, and where the cultivators with their 18 bushels average start from a vastly higher level, the promise of such a scientific ally should gladden the hearts of the hard-working pioneer.

One caution, however, I feel it my duty to give, as a practical rather than a scientific agriculturist. Whatever wonders are offered in the way of manurial adjuncts or mechanical contrivances, do not let our advisers overlook the paramount consideration of the cost which the newer systems may involve. For the extensive farming of a young country it is above all requisite to remember that expensive methods of cultivation are not as feasible as in the intensive husbandry of old settled regions. Hopefully as we may wait on the chemists's help, I confess that, for my own part, I incline still more confidently to the botanist, under whose ægis of protection agriculture has this year been placed by the decision of the authorities.

The producer of new and prolific and yet disease-resisting and frost-defying breeds of wheat plants is to-day more than ever encouraged by what has been done in many lands of late in this direction, to suit the crop to its environment. Nothing could be a greater boon to the wheat farmers, handicapped by a short and irregular supply of summer warmth, and the occasional but often untimely invasion of the frost fiend, than the production of varieties of wheat at once prolific and early ripening, and suited to the relatively scanty moisture of semi-arid regions. What success Canadian investigators, with their renowned experimental system, have had in this direction we hope to hear at Winnipeg, while some of us who have listened to Professor Biffen, of the Agricultural Department of Cambridge University, look for hopeful results from the application of Mendelian laws to the breeding of wheat.

In closing, let me add that though it is a quarter of a century since I last was here, the message I gave local agriculturists then is one I am tempted to repeat now. It is no use to treat the vast territories you have at your disposal as if they were a mere wheat mine to be exploited in all haste and without regard to its permanence and its future profitable development. It is unwise to proceed as if bread were the only item of food requiring attention at your hands, and to regard a spasmodic rush of grain for a limited number of years from a poorly tilled surface as the only way to profitable returns. The stale maxim of not carrying all your eggs in one basket has a very profound truth to rest upon. The farming of the future must ultimately be one of more careful tillage, more scientific rotations, and of consideration for the changes in the grouping of population and in the world-wide conditions of man and his varying wants. What is going on all over the world has to be learned and studied well, and wheat pioneers of the North-West must not forget the possibility of yet new competitors arising in the single task of wheat-growing, whether they are to be looked for in the still developing sections of the Russian Empire and the still open levels of Argentina, the little known regions of Manchuria, the basin of the Tigris and Euphrates, the more completely irrigated plains of India, the tablelands of Central Africa, or perhaps under new conditions and a more developed control of the reserves of water supply on the southern shores of the Mediterranean or even in the long tilled valley of the Nile.

The following Papers were then read:—

1. *Methods of Crop-reporting in Different Countries.* *By* E. W. Godfrey.

2. *Moisture Studies of Semi-Arid Soils.* *By* F. J. Alway, *B.A.*, *Ph.D.*

As the result of field and laboratory studies of soils from widely separated points in the semi-arid region of summer rains in North America, the author concludes that generalisations previously shown to apply to studies of soil moisture in Saskatchewan [1] apply also to the whole of the semi-arid region of summer rainfall from the Saskatchewan River on the north to the Mexican boundary on the south. The generalisations are:—

1. The determination of the 'hygroscopic coefficient' of the soils is, in many cases, indispensable for the intelligent interpretation of the moisture data, and is in all cases important.

2. The depth to which samples should be taken should extend at least as

[1] *J. Agric. Science*, vol. ii, p. 333.

far as the plants develop roots freely, or as far as the moisture descends from the surface. This depth can in most cases be approximately determined by a field examination of the soil.

3. The field notes of an investigator, based upon the appearance of the soil as removed by a soil auger often gives a more reliable indication of the moisture conditions than do the subsequent drying and weighing of samples, unless the hygroscopic co-efficient also be determined. In all cases the field notes are of value.

4. Conclusions based upon the moisture data when samples have not been taken to a sufficient depth, or when only the total water content of the soil is given, unaccompanied by determinations of the hygroscopic co-efficient or by the field observations, are certain to be in many cases entirely incorrect.

The data in support of these conclusions is drawn chiefly from western Nebraska, north-western Texas, central New Mexico, and south-eastern Arizona. The extremes of climate are herewith shown:—

	Av. annual precip.	Av. mean temp. for 5 mos. May to Sept.	Av. mean temp. for 5 mos. Nov. to Mar.
Douglas, Arizona . . .	10·5 ins.	76°	47°
Indian Head, Saskatchewan .	16·6 „	62°	12°

Soils of this region are, with a few exceptions, characterised by their ability to be reduced by the native vegetation and by many annual crop plants to a characteristic, easily recognised, dry condition. This state of dryness seems the normal condition in the more southerly regions, while in the north it may be found only at the time of the maturing of the plants. This property facilitates, in most places, the ready recognition of the moisture condition by a mere field examination with a soil auger.

A greenhouse experiment in imitation of the growth of wheat on fallowed ground was described. Semi-arid soil in 6-foot cylinders was saturated with water, thoroughly drained, and then planted with Red Fife wheat. No more water was added. The plants developed normally, ripening seed after 132 days. Photographs of the plants and tables showing moisture conditions were exhibited.

Joint Meeting with Section F.

The following Papers were read:—

1. *Agricultural Development in the North-West of Canada,* 1905 *until* 1909. *By* Professor James Mavor.—See Reports, p. 209.

---

2. *The Development of Wheat Culture in North America.* *By* Professor A. P. Brigham.—See Reports, p. 230.

FRIDAY, AUGUST 27.

The following Papers were read:—

1. *Some Economic Aspects of the Western Cattle Trade.* *By* Dr. J. G. Rutherford.

The methods of cattle production in the Canadian West are rapidly undergoing change, due to the rapid inrush of settlement and consequent

cultivation of the lands hitherto devoted to ranching. The latter industry is quickly disappearing, and though it may exist for some time in the more arid districts and in the Peace River country, it is bound to give way, eventually, before the settler.

The history of the Canadian range from 1879 to the present day shows the rapid development of the cattle industry; various difficulties and drawbacks have been experienced from time to time and there has been a deterioration in the class of cattle. Eastern stockers, and latterly Mexican cattle, have been introduced.

The Federal Government has improved the standard of production by encouraging the sales of pure-bred bulls.

The trade as now conducted is capable of much improvement. The methods of marketing cattle, especially those for export, are wasteful, unbusinesslike, and unprofitable to the producer. Grass-fed cattle, wild and soft, suffer much, and shrink badly, on the long railway journey to the sea-board. Conditions on Canadian cattle steamers are capable of being greatly improved. Business, badly conducted as it is, is profitable to the dealers, commission men, and railway and steamship companies, but unprofitable to the producer and to the country. It is advisable to finish our Western range cattle on grain and hay, of which the supply in Western Canada is unlimited, also to have better transportation facilities. Definite improvement in both these respects is already evident, and should be encouraged.

Development of a dressed meat trade is also necessary and desirable. This fact is appreciated by many Western men, but there is great difficulty in securing the necessary large capital for such an enterprise. In view of the experience of the United States with the Beef Trust it is advisable to have some measure of Government control.

Among the advantages of dead meat trade would be elimination of the present unavoidable heavy shrinkage in transport; regular and effective competition; steadying of present trade conditions; restoring confidence to producers who have hitherto suffered from dealers cutting prices when stock are plentiful and easy to obtain.

It is most important to have an export outlet for meat products in the possible event of the appearance in Canada of any of the diseases scheduled by the British Board of Agriculture. The United States has many large packing-houses fully equipped to handle dead meat, also widely separated seaports and railways along the Atlantic coastline. Canada is practically without abattoirs equipped for the slaughter of cattle, except for home consumption, has no refrigerator car system, few ships with the facilities for carrying chilled meat, only two winter ports, and railways close together. Continuation of the live stock trade is advisable. Canada is most favourably situated, both geographically and by reason of the exceptionally healthy condition of her herds, to carry on a profitable export trade in live cattle. There is ample room for both branches; each would balance the other, and if conducted in a businesslike way, both would be profitable to the country.

---

2. *Some Special Features of the Danish System of Cattle Breeding.* *By* Dr. P. A. Morkeberg.

Denmark, mainly an agricultural country, which formerly grew corn for export and raised very little cattle, began to turn its attention to dairy farming after the middle of last century. With the introduction of the centrifugal cream-separator and the building of co-operative dairy factories all over the country in the 'eighties, the system of dairy farming spread to even the smallest farms. The question of improving the two national

milking breeds, the black and white Jutland and the red Danish dairy cattle, became important and of interest to almost all farmers.

The work of improving cattle breeding in Denmark being, as explained, of fairly recent date, has been gradually developed in two quite distinct directions. Some features of the work aim at encouraging breeders to develop herds possessing the most valuable qualities of the breed, while other features aim at the better utilisation of the breeding animals from these superior herds for the improvement of the cattle breeding in general.

For the first purpose cattle shows and 'selection of breeding centres' have been found useful, while Cattle Breeders' Associations and Control Unions have helped in the other direction.

Cattle shows began about the middle of last century. At first all breeds and crosses competed together; from the 'sixties there were separate classes for the different breeds.

About the year 1870 the classes for single cows were discontinued and prizes offered instead for collections of cows bred by the exhibitor, a feature which is still considered very important, the idea being to draw attention to the best herds, which can more safely be done when a collection and not a single individual is shown. In 1887 the State caused to be held special shows for bulls over three years old for the purpose of encouraging farmers to keep the good bulls for a longer time. The result has been striking, the number of old bulls shown having increased from 371 to over 1,200. A special Danish feature has been introduced with these shows, viz., judging the bulls through their offspring, inasmuch as no prize is awarded for bulls over five years old unless their offspring, which must be judged before the show, have been found satisfactory. This entails a good deal of work, but has been found very useful.

The judges at shows take into consideration not only the points of the exhibited animal but also, in the case of bulls, the pedigree, including information of the milk production of the dam, and, in the case of cows, the milk production (quantity and quality).

Selection of breeding centres, in other words a systematic selection of the best herds, which then receive an official recognition as 'Breeding Centres,' is another special Danish feature introduced in 1884. The herds are entered for a competition which is carried on during two whole years by a committee of judges who visit the herds on the farms five or six times, while assistants on every twentieth day during the two years visit each of the competing herds, weigh the milk of each cow, test its percentage of fat, weigh the fodder given to each cow, and draw up the family herd book, in which the whole herd is arranged according to maternal descent, each animal being described with its sire and dam, milk production and prizes. At the end of two years' testing the committee of judges have acquired reliable information as to the value for use and for breeding of the different herds. The best herds are then designated as 'Breeding Centres,' with the result that the demand is increased for breeding animals from these herds at enhanced prices. A full report of the result of the two years' competition is published.

The Cattle Breeders' Association have for their principal aim the purchase of a good bull. The first association was formed in 1883. From the first these associations paid attention also to the cows and to the health of the herds; they required also accounts kept of the feeding and the yield of the individual cows. From 1887 the State gave a yearly grant which helped the movement on. There are now 1,300 Cattle Breeders' Associations with 1,500 bulls, the State giving 8*l*. per annum per bull on condition that the bulls have taken prizes, that the committee select the best cows of the members to be served by the bull, and that the committee at least once a year inspect the herds on the farms as to the state of health.

Much difficulty was experienced in keeping accounts of the food supplied

and the yield of the individual cows. The members could not manage these, and when in the beginning of the 'nineties information of the percentage of fat in the milk was included in the requirements it was found necessary to take this whole matter up in a different way. This led to the formation of the Control Union of Cow Testing Associations, which undertakes to strike a balance sheet for each individual cow that shall determine the daily feeding, the weeding out of unprofitable cows, and the selection of cows for breeding. Farmers in a district appoint jointly a 'controlling assistant,' who once every fourteen or twenty days visits each herd, weighs the milk of each cow, estimates the percentage of fat, weighs the food given daily to each cow, and keeps account of it all. He further keeps a book of the serving and calving, with all information necessary for the family herd book. The first Control Union was formed in 1895; now there are 479 with 10,925 members and 187,345 cows, comprising over 17 per cent. of the total number of cows in the kingdom. The work is carried on by 500 controlling assistants, the State giving a grant of 14*l*. per union yearly.

The information with regard to the yield and quality of milk of the individual cows collected by the Control Unions is taken into account in awarding the prizes at the shows, and is also made use of in selecting the cows to be served by the bulls of the Cattle Breeders' Associations.

---

3. *The Evolution of a Breed of Cattle. By* Professor J. Wilson, *B.Sc.*

Nearly every breed of cattle is a combination of several breeds: a result of crossing again and again and of subsequent 'pure' breeding. The modern Aberdeen-Angus breed is a case in point. It is the result of perhaps fewer crossings than some other breeds; but the ingredients used in its production are so decidedly varied, that a consideration of the way in which it has been formed yields the most highly instructive results.

In addition to the Urus, which became extinct in the Bronze Age, half a dozen different kinds of cattle have come to Britain at different times—viz. (*a*) the black Celtic race, which came in before the Urus was extinct; (*b*) the 'brown' race, black with a brown stripe along the back and a tan muzzle, which probably came with the Belgæ; (*c*) the white race, brought in by the Romans; (*d*) the red race, brought in by the Anglo-Saxons; (*e*) the hornless race, brought in by the Norsemen; and (*f*) the large flecked race imported from Holland in the seventeenth and eighteenth centuries.

When the Norsemen brought over their hornless cattle the rest of Scotland was occupied by the black Celtic race, with a considerable infusion of brown Belgæ and a smaller infusion of white Romans. These were all horned. In the eighteenth century many large cattle of the Dutch-flecked race were taken to the North-East of Scotland and crossed with the small native cattle, with the result that the native cattle gradually acquired the size of the flecked cattle. All this time the Norse cattle had been holding the seaboards of Forfar, Kincardine, Aberdeen, and Banffshires. In the middle of the eighteenth century a demand arose in England for hornless cattle; and to meet this demand the farmers in the North-East of Scotland crossed their horned cattle with the Norse hornless ones, with the result that the horns of the horned ones were removed. By selecting breeding stock that were black in colour, large in size, and hornless, the North-East farmers eliminated the undesirable characters of the various races of cattle that had been introduced to their country, and eventually produced their present breed.

4. *The Relationship of Manuring to Meat Production.* *By* Professor SOMERVILLE, *D.Sc.*

It has long been known that a large increase of herbage is secured from many classes of grass-land through the use of certain artificial manures, but in most cases the effects of the manures have been tested by simply weighing the increase secured. Sometimes the investigation has been carried further, and the herbage grown with and without manure has been separated into its constituent plants, and an attempt has been made to estimate the improvement in quality by the increase of such plants as clovers, and the suppression of such plants as sorrel and other weeds. Supplementary to such a botanical separation the herbage has sometimes been submitted to chemical analysis, and an attempt has been made to gauge the feeding value by the percentage and absolute weight of proteids, fats, and carbohydrates, and by the digestibility of the fibre. All these methods convey useful information, but as the ultimate object of producing herbage is to feed animals, and as no laboratory method can perfectly interpret the processes in an animal's stomach, it occurred to me that useful information might be got by utilising the animals themselves to pass judgment on the results.

My work has been chiefly confined to experiments on grass-land, and on grass-land they have been chiefly concerned with pasture as opposed to hay. In the United Kingdom there are some 34,000,000 acres under grass (apart from mountain grazings), and, of this, 24,000,000 acres are grazed and 10,000,000 are cut for hay. Clearly, therefore, the grazed area is of much more importance than that which is used for hay. To exclude stock from plots on a pasture, and to test the results of applying manures by weighing and analysing the herbage, must lead to a fallacious conclusion, for the reason that the mere exclusion of the stock encourages one set of plants and represses another, and the experiment resolves itself into one not on pasture, but on hay.

In 1896 the county of Northumberland rented a farm (Cockle Park) of 400 acres, of which I was given the scientific direction. A clay-field of uniform character, that had been under pasture of a poor type for many years, was divided by fences into ten plots of 3 $\frac{1}{10}$ acres each. Three acres of each plot have been grazed by sheep each summer for the past thirteen years, the herbage of the sub-plot of $\frac{1}{10}$ acre being annually made into hay. Specially selected sheep have been used for grazing the plots, the animals being individually weighed at the beginning of each season, and monthly during the progress of each grazing season. The health of the sheep on the comparatively limited grazing area of three acres has been all that could be desired, and any individual idiosyncrasies have been eliminated by the number of sheep (usually six to twelve) that grazed each plot. The system of experiment ('manuring for mutton') and the results have attracted a large amount of attention, and, aided by the Board of Agriculture, the experiments have been repeated, in part or in whole, in several parts of England and Scotland. It is only necessary here to call attention to the leading results, and chiefly to those obtained during the first nine years, the scheme being primarily designed to cover that period.

Lime has been used in two ways: (1) In two dressings of four tons per acre, and (2) in three dressings of half a ton per acre as a supplement to superphosphate. The former system is a very old one and popular with farmers, but neither at Cockle Park nor elsewhere have the experimnets shown it to be efficacious or profitable. At Cockle Park it only accounted for an average annual live-weight increase (which, for short, may be called mutton) of 12 lbs. per acre. Under the second method the ton and a half of lime has produced an average annual increase of 22 lbs. of mutton, and has left a small profit, as against a large loss in the other case. Basic slag, used in the first year only, at the rate of 10 cwt. per acre and a cost of 23*s.* 6*d.*, has produced an average

annual increase of 80 lbs. of mutton. Valuing this at $3\frac{3}{4}d.$ per lb. and deducting the cost of the manure, it means that a single expenditure of 23*s.* 6*d.* has given a clear annual gain of 22*s.* 3*d.*, or nearly 100 per cent. per annum, and even at the end of nine years the effects of the slag are by no means exhausted. On an adjoining plot 10 cwt. of basic slag has also been used, 5 cwt. being put on the first year and 5 cwt. at the end of the third. This method of treatment has produced an average increase of 66 lbs. of mutton, and although the profit here has also been large (averaging 18*s.* per acre per annum), it is considerably short of that secured under the other method of using the same manure. This result has been confirmed at the other duplicate stations, and shows that it is better to stimulate the superior plants by a large initial dose of phosphates than to spread the use of the phosphates over a longer period.

When the source of phosphoric acid was superphosphate instead of basic slag the cost was considerably greater, and the actual weight of mutton produced was distinctly less (57 lbs. per acre per annum, as against 66). The annual profit was therefore reduced from 18*s.* to 13*s.* 9*d.* per acre.

Adding potash to phosphate increased the yield of mutton to the extent of just covering the outlay involved.

When nitrogen in the form of sulphate of ammonia was used the yield of hay was increased some 25 per cent., but the annual production of mutton was actually reduced from 57 to 54 lbs. per acre per annum. This result was also obtained at all the stations, and shows how far mere weighing of the herbage may lead one astray.

Other manurial substances (cake residues and dissolved bones) were also tried, but the results of these, being more complicated, need not be discussed. Mention may, however, be made of the fact that at Cockle Park at the end of the ninth year a further dose of 10 cwt. of basic slag was applied per acre to the plot that had received a similar dose nine years previously, and the effects were seen in a large increase of mutton in the following years (1906, 1907, and 1908). This proves that there is little ground for the popular belief that grass-land fails to respond to a second application of a phosphatic manure. At one of the duplicate stations basic slag was applied to a plot in the middle of June, and before the grazing season was over the effects were clearly reflected in the growth of the sheep and in the appearance of the pasture. In the following year this plot, which had hitherto been the worst of the series, became the best. The opinion hitherto held that an insoluble phosphate, like basic slag, should be applied some months ahead of the growing season, must therefore be revised, equally good results following application when the herbage is in vigorous growth.

These experiments seem to show that probably no crop on the farm offers opportunities for more profitable use of artificial manures than poor worn-out pasture.

---

5. *The Development of the Dominion Experimental Farms.* *By* Dr. W. SAUNDERS, *C.M.G.*

The author referred briefly to the depressed condition of agriculture which prevailed in Canada prior to 1884 and to the appointment by the Parliament of a Select Committee to inquire into this subject and to suggest remedial measures. The report of this committee led to the establishment of Experimental Farms in Canada, institutions which were to be so managed as to conduct experiments in all branches of agriculture and to disseminate the information gained in annual reports and bulletins, which were to be widely distributed among farmers.

An Act was passed by the House of Commons in 1886 by which five of these farms were established in different parts of the country. The encouragement

thus given to agriculture has led to greatly improved conditions. The benefits thus conferred on farmers have led to a demand for an increase in the number of these institutions, which have been gradually increased to nine with four smaller experimental stations.

The main features in the work carried on at the Central Experimental Farm at Ottawa, covering all branches of work relating to agriculture, were referred to, also the locations of all the Experimental Farms and stations established to the present time and the lines of work which they have conducted, and those which, from their climatic and other conditions, they are specially fitted to conduct in the future.

Reference was also made to the helpful encouragement which the Dominion Experimental Farms have afforded to Canadian agriculture.

---

6. *The Fruit Industry of British Columbia.* *By* J. C. METCALFE.

MONDAY, AUGUST 30.

Joint Discussion with Sections B and K on Wheat.
See Appendix A.

TUESDAY, AUGUST 31.

The following Papers were read:—

1. *The Outlook for Timber Supplies.*
By Professor W. SOMERVILLE, *D.Sc.*

Much attention has recently been given to this subject, and the general opinion is that prospects are not reassuring. Britain paid twenty-seven millions sterling for wood on the average of the five years 1904-8, as compared with eighteen millions 1889-93, an increase of 50 per cent. Even Germany, with nearly twelve times the area of forest that we possess, pays annually some twelve millions sterling for imported timber. Although the U.S.A. exports wood and wood-products to the value of twenty millions sterling per annum, she has to pay as much for imports. In Europe, Sweden and Russia are the chief timber-exporting countries, and it seems unlikely that these countries can maintain supplies. Sweden, it is officially stated, is over-cutting her forests to the extent of more than 100 million cubic feet yearly, while Russia is already reducing her exports. In various official publications the Department of Agriculture of the United States has drawn attention to the prodigal method in which her forests are exploited, and has pointed out that in a few years she will not even have timber enough for her own supplies.

There are only two regions of the world that may contain sufficient areas of virgin coniferous forest appreciably to affect the situation. The one is Canada, which in the North-West, and also North and East of Lake Superior, contains large tracts of untouched forest. The growing stock of large stretches of country west of the Rocky Mountains is undoubtedly large, and is now having an appreciable effect on market supplies. The timber that may become available along the line of the new Grand Trunk Railway is much more problematical. The area is vast, but the density of the stock is said to be poor, and the individual trees and rate of growth are small. The other region of the world that contains large

stretches of virgin forest is Siberia. Although the density of Siberian forests cannot compare with well-stocked land in Europe or America, her areas are so vast that it cannot be doubted that this country possesses enormous stores of wood. But the difficulty in her case is to get them out. The navigation of the Arctic Ocean is too dangerous to be undertaken for timber cargoes at anything like present prices. Nor would it be profitable to move timber along the Trans-Siberian Railway. The only way to get part of Siberia's timber to market is to float or ship it down the rivers, such as the Amur, that debouch into the Pacific. This is already being done to some extent, and in time such supplies will go some way towards satisfying the demands of China, Japan, and Australia.

The growing scarcity of supplies of timber is clearly reflected in the prices on the world's markets. Thus in Britain the largest class of timber has risen in value 28 per cent. in the last fifteen years. Concurrently with the rise in price there has been a marked falling off in quality, so that the real rise in price has been much more than the figures indicate. The United States Department of Agriculture recently issued a table, which showed the prices ruling for various classes of timber in various American markets during the past twenty-two years. Of thirty-two brands of timber, nine had risen over 100 per cent., and only two had risen less than 25 per cent. Effective relief through the agency of timber substitutes seems improbable. Concrete and iron are, of course, used to some extent in place of wood, and there is a talk of sugar-cane stalks becoming important in paper-making. But with it all, the demands for wood continue to grow, and although economic prophecies have often proved to be wrong, it seems impossible to escape the conclusion that the future of the world's timber supplies is distinctly disconcerting. It would therefore appear to be in the interests of every country to take energetic steps to prevent the wasteful destruction of timber by forest fires, to see that denuded areas are at once regenerated, and to undertake the planting of all land that can be better utilised under silviculture than through the agency of pastoral occupation.

---

2. *The Forests of Canada.* *By* R. H. Campbell.

The area of forest in Canada containing timber of present value is probably not more than 500 to 600 million acres, and the area which can be considered as entering into the question of a supply of lumber is probably one half of that area, with a stand of 500 to 600 billion feet board measure. The quantity of pulpwood is large, and may equal one billion cords.

The present production in Canada annually is about ten billion feet board measure of all wood products, of which four billion would be timber of a size suitable for sawing into lumber. If the production did not increase rapidly beyond this figure the supply would last indefinitely, but when the possibilities of the future are considered in relation to the consumption in the United States of forty billion feet board measure of lumber and a possible total of one hundred million feet board measure of wood products, and to the net imports of the Continent of Europe, which is several billions, the fifty billion feet board measure of pine of merchantable size still standing in Canada, does not give a large outlook for future expansion, and even the 300 billion feet estimated for the best timber of British Columbia cannot be termed inexhaustible.

Pulpwood is an uncertain, though a large quantity, and there seems no danger, even with a greatly increased demand, of early exhaustion, but a large part of the stand is on the Arctic and Hudson Bay watersheds, and therefore not readily available for other than domestic consumption; railway construction and settlement are advancing into these northern districts, and

forest fires are still in dry seasons destroying large areas of mature forest and young growth.

The action as yet taken by the Government to deal with the situation is entirely inadequate. The areas and distances are great, the population is sparse and scattered, the expense of an adequate system is high. The policy which should be followed may be summarised as follows:—

(1) The fire patrol should be strengthened and made as effective as possible. While not, as at present organised, a thorough or adequate system, it is the only possible method under present conditions, and has been productive of great good.

(2) An exploration of the public lands should be made in advance of settlement, and lands not fitted for agricultural purposes should be segregated and administered for forest purposes. Until forest lands are definitely separated from other lands with a clear understanding that they are to be administered on a fixed policy of permanent forests, administration must be uncertain and ineffective.

(3) The question is finally one of administration, and to deal with it a trained staff must be built up, having knowledge of advanced systems of forest administration; having a practical knowledge of the business of lumbering; having the faculty of observation trained to see the various phases of the forest problem and the conditions which affect it, and having practical common sense and business sagacity.

(4) Careful study of local conditions, forestic, economic, political; and experimental work to determine what methods of reforestation and management will be most successful.

(5) Education.—First, public education. This is a democratic country, and any public action must have public support. Second, special education. The training of the administrative staff in the school and in the forest.

The three divisions of the work are:—(1) Education, (2) Legislation, (3) Administration. Of these the means for special education are sufficient. The work of public education is being carried on vigorously, but requires great extension. Legislation is generally advanced. The carrying out of the results of education and legislation is in the hands of the administration, which is utterly inadequate and incapable as at present constituted for the large task it has before it. A trained staff equal to the situation must be developed. This is a work of time, and demands that the beginning tentatively made should be expanded rapidly.

Canada has a great extent and wealth of forest, but it is gradually and surely being depleted from year to year. Under present conditions she may continue for years her position as an exporting country, but fire and the axe are reducing her producing capacity steadily, and the foreign and domestic demand are as steadily increasing. Reproduction is not offsetting destruction—far from it—and the efforts so far made to assist it by artificial means are hardly worth mentioning. When the present stand of mature timber is gone, Canada cannot remain an exporting country unless some more effective steps to protect and reproduce her forests than those now attempted are undertaken.

---

3. *Some Injurious Insects of Canadian Forests and Methods of Control.*
By Professors W. Lochhead *and* J. M. Swaine.

In spite of the enormous area of the Canadian forests (estimated at 1,600,000 square miles, of which at least one-fifth may be assumed to carry valuable timber), no Government survey has ever been instituted with the definite purpose of determining the amount of damage done by insects and fungi. This paper summarised what little is known from the observations of individual collectors, foresters, and lumbermen, together with what may reasonably be inferred from the admirable work of the Bureau of Entomology

of the United States Department of Agriculture upon forests contiguous with those of adjacent territories of Canada.

Fuller knowledge of the life history of the most injurious species is required before specific remedial measures can be devised. Among those of general application are the prompt removal of mature timber and the destruction of harbouring refuse.

---

4. *Some of the most Injurious Insects of Field Crops in Canada.* *By* Professor William Lochhead.

Competent observers estimate the loss from depredations by insects to field crops in Canada at not less than fifty millions of dollars annually. While the loss cannot be wholly prevented, it could be greatly reduced by the general adoption of the measures advocated. In Eastern Canada the Hessian fly is doubly brooded, the fall brood appearing in September and attacking the young plants of fall wheat, the spring brood appearing in May and June and injuring fall wheat as well as spring crops of wheat and barley. In Manitoba it is apparently single brooded, the puparia remaining dormant on the stubble until spring. The method of control recommended for the West is to burn over the stubble of the wheat fields or to plough the stubble land down deeply as soon after the crop is cut as may be practicable.

Wireworms and white grubs were dealt with. The remedial measures considered were chiefly the systematic rotation of crops.

---

5. *Chemical Characteristics of Western Prairie Soil.* *By* Frank T. Shutt, *M.A., F.R.S.C.*

The Canadian prairies comprise all that portion of the Great Plains Region north of the forty-ninth parallel and found within the confines of the three western provinces, Manitoba, Saskatchewan, and Alberta, and extending northward of these provinces to the Arctic Ocean. It consists of a stretch of country of some 800 miles from east to west, if measured along the southern boundary of these provinces, but contracting to between 300 and 400 miles at the fifty-sixth parallel. Settlement began in the south of this country, and for some years past has been rapidly extending northward. This interior plain is made up of three steppes. The first and lowest (with an elevation of 800 feet above the sea) is known as the Red River Valley; its northern part being occupied by the Winnipeg lakes, while its southern portion constitutes an apparently absolutely dead-level prairie of almost 7,000 square miles. It is the bed of the ancient glacial Lake Agassiz, the sediment of which is found to make the finest soil for wheat.

The second steppe, west of the above and extending to the Missouri coteau, has an average altitude of 1,200 feet and comprises some 105,000 square miles, the soil being undulating in parts and less uniform in character than that of the first plateau.

The third and largest steppe, extending westward of the above to the foot hills of the Rocky Mountains, comprises the western part of Saskatchewan and the province of Alberta. Its average altitude is about 3,200 feet and its area 134,000 square miles. The northern part is wooded, while an open prairie occupies the greater portion in the south. Its topography is more diversified than that of the first and second plateaux.

The meteorological features of this prairie country are high day temperatures and an abundance of sunshine in the summer months, and an annual precipitation of, say, 18 inches in the eastern portion, declining to, say, 14 inches in the western. An important fact from the agricultural standpoint is that from 70 to 75 per cent. of this rainfall occurs during the months of early growth and is therefore particularly effective for cereal crops.

During the past twenty years some 200 samples of soil collected from widely distant points over this immense area have been analysed, though all have not been subjected to a complete examination. As a result of this work it can be unhesitatingly stated that the essential and distinguishing feature of the western prairie soils is their high organic matter and nitrogen content. It is to this fact unquestionably that they primarily owe their remarkable fertility and lasting quality. They contain for the most part fairly abundant stores of phosphoric acid, potash, and lime. We have, however, no evidence that the prairie soils, as a class, are exceptionally rich in these elements, though the presence of lime in liberal amounts indicates a condition of the soil particularly favourable to nitrification. The very intimate incorporation of this semi-decomposed vegetable matter with the clay and sand constitutes a very important and valuable feature and undoubtedly has an influence for good in many directions. The large percentage of this humus-forming material beneficially affects the soil from all three standpoints—chemical, physical, and biological. The relation between organic matter and nitrogen is a very close one; whatever destroys the former dissipates the latter.

It is to be noted that in prairie districts the soil may be found of an extremely uniform character over very large areas, and that, as a rule, the decline in organic matter and nitrogen from above downwards is gradual, there frequently being no distinct line of demarcation between surface and subsoil.

The nitrogen content of the Manitoban soils examined ranged from ·2 to 1·0 per cent., the larger number falling between ·25 and ·35 per cent. In Saskatchewan, the samples from eight or ten districts revealed a nitrogen content from ·2 to ·5 per cent. In Alberta many of the types analysed contained between ·3 and ·5 per cent., but the average was not quite so high as for the two provinces to the east. As a rule, it was found that lower nitrogen percentages are obtained as we proceed westward across the plains, and undoubtedly there is a direct relationship between the rainfall and the amount of nitrogen accumulated in the virgin prairie soil.

The water-holding capacity of these soils rich in humus-forming material is very large, and it is to this fact that fallowing, now in vogue in grain-growing districts, largely owes its value. Moisture may be stored by this practice for the crop of the succeeding year, and from 200 to 300 tons of water per acre foot (over and above that otherwise present) thus supplied to the young crop at a time when the moisture can be used to the greatest advantage.

The system of grain-growing now in practice leads to a large loss of nitrogen annually; probably twice as much loss of this important element being due to fallowing and other farming operations as to cropping. The following table presents the data from one set of experiments to illustrate this nitrogen depletion:—

Indian Head, Sask.

—	Nitrogen.			
	To a depth of 4 inches.		To a depth of 8 inches.	
	per cent.	lbs.	per cent.	lbs.
Virgin soil	0·409	3284	0·371	6936
Cultivated 23 years (including nine fallows)	0·257	2402	0·253	4730
Loss due to removal in crops and to cultural methods	0·153	882	0·118	2206

Calculation shows that about one-third of this loss is to be accounted for by removal in grain and straw of the crops grown, the remaining two-thirds being dissipated by cultural operations.

It is highly important that a system of crop rotation that will occasionally return humus-forming material and nitrogen should replace the present system of two grain crops, followed by a bare fallow. It will only be in the adoption of some such method that the present high fertility of the prairie soils can be maintained.

---

6. *The Nitrogen Problems of Dry Farming.*
By F. J. Alway, *B.A., Ph.D.*

Fallowing, which in 'dry farming' is necessary in order to accumulate water in the subsoil, facilitates the rapid loss of nitrogen, while the use of leguminous crops as green manures exhausts the moisture of the subsoil. The nitrogen problem will probably become acute much sooner in the central and southern portion of the semi-arid region than in Saskatchewan, as the original content of nitrogen is less. Six-inch samples of the heaviest types of soil, which are also those richest in nitrogen, were taken by the author from prairies in widely separated portions of the semi-arid region, viz., Indian Head, in Saskatchewan; North Platte, in Nebraska; Solana, in northern New Mexico; and Douglas, in south-eastern Arizona. The percentages of nitrogen were ·384, ·175, ·161, and ·087 respectively, and of organic carbon 4·19, 2·06, 1·29, and 0·58.

The author reported the results of the determination of nitrogen, organic carbon, and soluble humus in over fifty samples of soil taken by him from different fields, plots, &c., of the Indian Head Experimental Farm, as well as from the adjacent prairie. The history of all the fields since the first prairie sod was turned is known. Continuous cropping with wheats, oats, and barley, with a fallow about every third year, has caused a loss of about one-third of the original content of nitrogen and carbon. Continuous bare cultivation for fifteen years has caused noticeably greater losses than cropping for the same length of time. Seeding down to grasses has checked the losses. In the case of a field of twenty-two rotation plots the average of the fifteen plots, on each of which during nine years a leguminous crop had been ploughed under every third year, was the same as that of the seven plots which had produced a cereal crop every year or had been fallowed every third year.

That nitrogen has not yet become a limiting factor in the yield of wheat at Indian Head is shown by the annual reports of the Indian Head farm. Applications of 100 and 200 lbs. of $NaNO_3$ have caused no increase in yield of wheat. The yield after leguminous crops ploughed under has been less than on fallows, the difference in yield seeming to depend upon the extent of growth and the lateness of ploughing of the legumes, and accordingly upon the amount of water removed from the soil by the legumes.

---

7. *The Conservation of the Fertility of the Soil.*
By A. D. Hall, *M.A., F.R.S., and* E. J. Russell, *D.Sc.*

Nitrogen is the most important of the elements of fertility in the soil, and the one most subject to change through either the natural conditions prevailing or the form of cultivation the land receives. We may distinguish various factors affecting the amount of nitrogen in the soil:—

(1) The growth of plants simply removes some of the nitrogen that has

reached an available form. As it may also be accepted that the plant itself, apart from bacterial action, neither converts any of the combined nitrogen it obtains into gas nor brings into combination any of the free nitrogen of the air, there is neither gain nor loss of soil nitrogen when the growth of the plant is returned to the soil.

(2) Various bacteria are capable of bringing atmospheric nitrogen into combination and so increasing the stock of soil nitrogen. They may either live in symbiosis with higher plants (Pseudomonas) or exist free in the soil (Azotobacter, Clostridium).

(3) Another group of bacteria, in the process of breaking down organic matter, liberate the nitrogen in the free state and so reduce the stock of soil nitrogen.

(4) Natural drainage waters contain nitrates which have been derived from the soil nitrogen by bacterial oxidation.

(5) The rain annually contributes a certain amount of combined nitrogen to the soil. The amount is greater in the proximity of towns; the average amount at Rothamsted is 3·84 lbs. per acre per annum, and other results would show that this is a very representative figure for pure country air.

The interplay of these factors gives rise in practice to the following types of cases:—

A. The nitrogen content of land under arable cultivation declines when the produce is entirely removed and no organic nitrogen is added as manure. The unmanured plot on the wheat-field at Rothamsted shows the following results:—

Broadbalk, Plot 3. *Nitrogen, lbs. per acre.*

In Soil, 1865	In Soil, 1893	Loss in 28 Years	Added by Rain and Seed	Removed by Crop	Unaccounted for
2,722 lbs.	2,437 lbs.	285 lbs.	167 lbs.	428 lbs.	−24 lbs.

Thus the crop almost exactly accounts for the decline in nitrogen in the soil + that which has been brought down by the rain. Since there are also losses due to drainage and to the nitrogen contained in the weeds removed from the plot, there must be some recuperative actions (No. 2) at work to maintain the balance. These, however, are not large. Taking similar figures for plot 7, which receives 86 lbs. of nitrogen annually as ammonium salts:—

Broadbalk, Plot 7. *Nitrogen, lbs. per acre.*

In Soil, 1865	In Soil, 1893	Loss in 28 Years	Added in Manure	Added by Rain and Seed	Removed in Crop	Unaccounted for
3,034 lbs.	2,971 lbs.	63 lbs.	2,408 lbs.	167 lbs.	1,212 lbs.	−1,426 lbs

In this case the recuperative agencies are not sufficient to balance the losses by drainage water, weeds, &c.

B. When land rich in organic compounds of nitrogen is subjected to arable cultivation, the destructive agencies (No. 3) become very active and the land loses nitrogen rapidly. This may be illustrated by the results obtained from plot 2 on the same field, which receives 14 tons of farmyard manure, containing approximately 200 lbs. of nitrogen, every year.

Broadbalk, Plot 2. Nitrogen, lbs. per acre.

In Soil, 1865	In Soil, 1893	Gain in 28 Years	Added in Manure	Added by Rain and Seed	Removed in Crop	Unaccounted for
4,343 lbs.	4,976 lbs.	633 lbs.	5,600 lbs.	167 lbs.	1,361 lbs.	−3,773 lbs.

Under these conditions the losses are enormous, amounting to about one-half of the nitrogen added.

C. When land is carrying a natural vegetation which is not removed there is a gain of nitrogen. A portion of the Broadbalk wheat-field has been allowed to run wild since 1881; a rough natural vegetation, consisting mainly of grasses, but also containing about 25 per cent. of leguminous herbage, has established itself and is never removed, but allowed to fall and decay. Analyses of the soil in 1904 showed a considerable accumulation of nitrogen.

Nitrogen, lbs. per acre, top 9 inches.

In Soil, 1881	In Soil, 1904	Added by Rain (23 Years)	Gain
2,769 lbs.	3,711 lbs.	88 lbs.	851 lbs.

There is also a considerable gain in the second and third nine inches.

A similar piece of land on which the vegetation is exclusively grassy and contains no leguminous plants shows a smaller but still marked gain of nitrogen. This gain may be attributed to bacterial agencies (No. 2). Not only are there leguminous plants in the plot, but azotobacter is also present, and is enabled to fix large quantities of nitrogen because it obtains the necessary carbohydrate from the annual fall of vegetation. Fixation is small on the unmanured arable plot (A) because only a small root residue of carbonaceous matter is left in the land every year. It is to the activity of azotobacter when thus supplied with carbohydrate by the annual fall of vegetation that we may attribute the accumulation of nitrogen in virgin soils. The higher plants alone, however long they occupied the land, could only restore what they had previously taken from the soil, and thus could never originate the vast stores of nitrogen that are found in such virgin soils as the black steppe soils of Manitoba and the North-West. This conclusion is strengthened by the fact that such steppe soils are always well supplied with calcium carbonate, a necessary factor in the action of azotobacter. The organism itself has also been isolated from all such soils.

From the practical point of view we may conclude that the cultivation of successive cereal crops will rapidly reduce the stock of nitrogen originally in the soil, not only by the amounts withdrawn in the crop, but also by the oxidising actions which are set up in the cultivated land. By a more conservative system of farming, in which leguminous crops are introduced into the rotation and a certain amount of carbonaceous matter is returned to the soil, the recuperative agencies become sufficient to repair the losses of nitrogen and maintain a moderate level of fertility without the introduction of any extraneous source of nitrogen. Such, indeed, was the state of things in Europe previous to the discovery of artificial fertilisers, *e.g.*, the average production of wheat in England in the early years of the nineteenth century was about 20 bushels per acre on farms which were self-supporting as regards the elements of fertility, and this level has been maintained for a long time.

This conclusion may be illustrated from the results given by the Agdell Field at Rothamsted, which is farmed on a four-course rotation, with clover

or beans once in each four years. Taking the plot which receives no nitrogen, but only phosphoric acid and potash, we obtain the following figures:—

Nitrogen in Soil			Average Production				Average Removal of N. per acre per annum
1867, lbs.	1909, lbs.	Gain or Loss per acre per annum	Wheat, bushels	Swedes, cwts.	Barley, bushels	Clover, cwts.	
3,240	3,522	+6·7	35·2	227	29	46·7	46·3

Had the roots, straw, and clover hay been converted into manure and returned to the land, as would be the case in ordinary farming, there is little doubt but that the production would be raised to the usual English level of 32 bushels of wheat, 34 bushels of barley, 12-13 tons of roots per acre.

---

8. *The Functions, Availability, and Conservation of Soil Moisture in Crop Production. By* Professor F. H. King.

The author pointed out the great importance of soil moisture as a factor in crop production, not only in dry countries but in moist ones as well; indeed, it is doubtful if there are any agricultural soils to be found anywhere where deficiency of available moisture is not, in most seasons, a marked limiting factor of yield. Water is not only an important plant food, but is also the medium in which all other plant food derived from the soil is elaborated and carried to the plant tissues. To produce a ton of dry matter in the crop from 250 to 600 tons of water are withdrawn from the soil by transpiration and by evaporation from soil. It is not possible to separate these two factors, but in the author's view the plant takes not less than from 200 to 400 tons. To produce twelve bushels of wheat and twenty bushels of barley per acre there must be lost from the soil not less than 3·6 and 4·3 inches of water respectively, and there must be left in the soil at harvest enough water for growth not to have been stopped.

Only a portion of the water in the soil is available for the crop; the rest is held as a film to the soil particles and cannot get into the plant roots. The amount of this unavailing water depends on the size and arrangements of the soil particles and on the quantity of colloidal matter present. Thus a soil may be physiologically dry and yet contain more moisture than another soil which is actually supplying water to plants. Further, on one soil (*e.g.*, a coarse sand) 0·3 inch of rain would double the water content of the surface foot and place it in a good growing condition, while on another soil (*e.g.*, a clay) the same rainfall would be largely retained near the surface, above the roots, and be quickly lost by evaporation. On the sandy soil also the rain would have dissolved any soluble salts accumulated near the surface and have carried them down about the surfaces of the active root hairs so that the crop would have been fertilised as well as watered; on the clay soil the water might even have the effect of strengthening the upward capillary rise from below, leaving the deeper soil both drier and less richly charged with soluble plant food than before. When the natural particles are caused to agglomerate by tillage, the amount of available water increases; suitable soil texture is therefore a very important consideration in dry farming.

Another important matter is the depth of the soil. Where the textural conditions of the subsoil are uncongenial and a large root surface is forced to be developed in a small volume of soil, the demands of the plant for

moisture may become so large that the rate of removal from the soil exceeds the ability of capillarity to bring it up. In many of the coastal plains of the Southern States (U.S.A.), where such soil conditions obtain, drought often prevails with a high water content in the soil less than 18 inches below the surface. It is a fortunate circumstance that deep congenial subsoils are generally characteristic of semi-arid and arid regions, so that the root systems of crops may have deep as well as broad pasturage, and upon this feature more than any other must the hope of 'dry' farming rest. Earth mulches are next discussed, and it is shown that the mulch should not be deeper than necessary. Not only is a deep mulch so much soil taken out of active service, but it may, in a season of small intermittent rains, waste more moisture than is saved by retaining the rainfall at the surface, whence it evaporates, instead of allowing it to penetrate below.

For hoed crops like maize and potatoes it is easy to utilise soil mulches as conservators of moisture, but with cereals a modified method is necessary. The author recommended growing cereals in strips two feet wide, leaving two feet as cultivated fallow between the strips. In the following year the strips are alternated, so what is now fallow will next year be cultivated, and *vice versâ*. He considers this better than the usual arrangement of leaving the whole field fallow in alternate years.

SECTION L.—EDUCATIONAL SCIENCE.

PRESIDENT OF THE SECTION.—REV. H. B. GRAY, D.D.

THURSDAY, AUGUST 26.

The President delivered the following Address:—

The Educational Factors of Imperialism.

AMONG all civilised races and in all epochs of the world's history there has existed an inveterate belief that the particular age in which men live is fundamentally distinct from those that have preceded it.

Even in the most stagnant periods the illusion has prevailed that *the present day* is a period of flux and movement more or less organic, and as such either to be welcomed or to be deplored.

Notoriously difficult, however, as it is to gauge the temper of an age while we live in its midst, yet the phenomena in England at the beginning of the twentieth century seem so unmistakably marked, that even a superficial thinker can hardly fail to recognise the spheres in which the symptoms of change and unrest are clearly operating. They are surely in these two —the sphere of education and the sphere of Imperial sentiment.

It may not appear inapposite, therefore, if, meeting as we do in this city of phenomenal growth and infinite enterprise, our thoughts were to be directed in my inaugural address on the Science of Education towards discovering what may be either called the Imperial factors in education, or conversely, and perhaps more properly, the educational factors in Imperialism.

It may be perhaps safely said in this great Dominion what might possibly be disputed in the academic groves of our ancient English universities, that there was no width of educational outlook within our own little island until the last thirty years of the nineteenth century.

The only strongholds of learning which presumed to give the lead to English secondary education were to be found on the banks of the Isis and the Cam. In these antique, I hesitate to say antiquated, fastnesses, the 'grand old fortifying classical curriculum' was, till lately, regarded as the main, if not the only, highroad to educational salvation. They preserved, indeed they preserve to this day, almost the same entrance bars against admission to their thresholds as existed in pre-Reformation days. And, conformably with the pursuit of these ideal studies, the vast mass of their emoluments were, and still are, appropriated to the pursuit of the ancient models of education.

The result of this monopoly on the lower rungs of the educational ladder has been obvious, and, to a scientific thinker, lamentable. The *curricula* of the Public Secondary schools have been narrowed, or rather have never been widened coincidently with the development of new spheres of knowledge and enterprise. The students in those institutions have been dominated from above, for just as 'where the carcase is, there will the

eagles be gathered together,' so where the emoluments have been, thither do the cleverest students concentrate their intellectual forces.

The ambition of the ablest boys has been inevitably and exclusively concentrated on a single line of study, and (as often happens in the minds of the young) other no less humane but entirely unendowed departments of human knowledge have been laughed down and despised. Opprobrious epithets even have been bestowed on the study of the natural sciences, while those modern linguistic achievements which opened the door to the treasures of French and German literature are still nothing accounted of in the great schools of England.

But (more marvellous than all) even the scientific acquisition of and familiarity with the literature of the mother tongue have been entirely neglected, because no room could be found for it in a time-table, three-quarters of which is confined for the great mass of boy students in the historic schools of England (whatever their tastes and capabilities) to the exclusive study of the grammar, literature, and composition in the languages of ancient Greece and Rome. And the particular methods pursued in this confined curriculum have rendered the course more straitened still. The acquisition of the literatures of the two dead languages and of the great thoughts buried with them have given place to a meticulous study of the subtleties of scholarship, and students are taught to wanton in the abnormalities of the words and phrases in which those literatures were enshrined, so that in the mind of the classical scholar the form has become, or at any rate became till quite lately, more important than the substance.

Nor is this all. Those who cannot find any stomach for such drenching doses of mediæval learning are actually driven away prematurely as lost souls from those moss-grown seats of learning, which we acclaim as the great public schools of England; and, with moral characters only half-fledged, have either been condemned to the limbo of private tuition or sent as 'submerged tenths' to find, or lose, their fortunes in the great dependencies and dominions of the Empire like that in which I am speaking to-day. There has been no serious attempt made till the twentieth century by the leaders of our best-known places of secondary education to discover the bents and aptitudes of the boys committed to their charge and to give them any educational chance, if they have not possessed that particular kind of perception which could find its way through the subtleties of a Euripides or a Horace. Boys have been entirely denied the opportunity of showing their mental powers in any other sphere of learning. How many unsung Hampdens or mute inglorious Miltons of mechanical genius have been lost to the world by the non-elastic systems prevailing (even now) in our best-known educational institutions, is a tremendous responsibility for conscientious trainers of the young to contemplate and atone for.

In how many, or rather how few, places of learning in England, at the present time, can the establishment of scientifically equipped carpentering and engineering shops be found, in which a young mind which finds it impossible to digest the crude morsels of Latin and Greek grammar can find resource and development? In how few schools has the connection between mind and hand and eye been scientifically trained? Such establishments, even in the first decade of the twentieth century, can be counted on the fingers of one hand.

And yet, in spite of it all, the surprising fact remains—a fact which speaks volumes for the innate vigour and originality of the English race—that, out of the stream of young men which flows out annually from our public schools [1] and colleges, so many accommodate themselves as happily

[1] It should be noted in the forefront of this address that the expression 'public schools' is used throughout in its English (not in its more proper and American) sense—*i.e.*, as the educational centres of the upper classes.

as they do to the startlingly new conditions which confront them when they pass over the seas, and swell the tide of population in great centres of industry and enterprise such as that in which we stand to-day. Their educational vision, however, has had such a narrow and limited horizon that no wonder a large proportion are not very adaptable to the practical life of the prairie and the forest, or even of the counting-house and the office stool. Am I, or am I not correct in hazarding the conjecture that many specimens of this really fine English breed from the old country come to you here in this Dominion without an elementary knowledge of the laws of the world in which they live, full of antiquated prejudice and tradition, derived principally from the straitened area of their island-home experience, so that not seldom they put their hand to the plough (either literally or metaphorically) and look back, becoming wastrels instead of forceful citizens in this ever-widening Empire? 'No English need apply' has been, if I mistake not, written as a memorandum inside the breast of more than one leader of industry in this great continent, and small wonder is it when the cramping character of the ultra-mediæval training which our young men have received at some of our historical public secondary schools in England is taken into account.

What remedy (you may ask) have I to propose? My answer is this: I want to force upon the attention of English educationists certain Imperial factors which should occupy an indispensable place in the educational curricula of the great schools in the Mother Country.

I would give a prominent place to the scientific teaching of geography, and particularly to historical geography, with special reference, of course, to the origin, growth, and progress of the British Empire. Such a volume as the 'Sketch of a Historical Geography,' by Keith Johnston, should be placed in the hands of every boy, and be known by him from cover to cover. It can hardly be realised that in many of our great classical schools to this day not more than one or at most two hours a week are devoted to this subject, and that it is often not taught at all beyond the middle classes in a school.

Again, I would enforce an elementary knowledge of science on every boy who passes through the stage of secondary education.

I am aware that many hard things have been said about the teaching of science in secondary education. A learned professor, who is the President of another Section of the Association, has passed his opinion that, as taught in our schools, it has proved of little practical or educational value. But because the methods employed have been halting, insufficient, and unscientific, it by no means follows that it should be left out of the category of school subjects. On the contrary, it appears astounding that two-thirds of the public school boys of England should grow to man's estate without even an elementary knowledge of the laws of the world in which they live.

Lord Avebury, in his Presidential Address at the International Moral Education Meeting held in London last autumn, told his audience an amusing story of how, walking back one beautiful summer night from the House of Commons arm-in-arm with a leading luminary on the Government benches, his companion, who had been at Eton and Oxford, gazing at the greater luminary in the heavens, pensively observed: 'I wonder, my dear Lubbock, whether we shall ever know why the moon changes her shape once a week at least?'

To one who aspires to seek his fortune in the wide and half-unexplored continents of Greater Britain the value of the knowledge of chemistry, geology, botany, and arboriculture, can hardly be over-estimated. And yet many present here could bear critical witness to the fact that a large proportion of young men go out to the North-West totally unequipped after their public school training with even the most elementary knowledge of those departments of science to which I have alluded. No wonder, again, 'No

English need apply.' Every youth we export to you ought educationally to bear this label on his back: 'Every seed tested before being sent out.'

But above and beyond all there should be brought into the foreground a co-ordinated study of English language and English literature. Nothing impressed me more in my visit to the United States in 1903 as one of the Mosely Commission, than to observe how greatly the cultivated classes in the Federation outstripped our island-bred people in the facility and power with which they manipulated the English tongue. Awkwardness, poverty of expression, and stammering utterance mark many Englishmen of high academic distinction. But the American who, on account of the incessant tide of immigration, has to assimilate the congeries of all the nations of the earth in the shortest possible space of time, has so co-ordinated the study of his ancestral tongue in the schools of his country, that the pupil emerges completely equipped for the use of persuasive and oratorical language wherein to express his thoughts and wherewith to gain his ends.

In connection with this may I add that it was, indeed, a happy augury that, at the eve of the meeting of the British Association in this great Dominion, there should have been a gathering of delegates of the Imperial Press in the centre of our small island home. 'Little they know of England, who only England know.' The phenomenal, or rather abysmal ignorance of the geography and of the vastness of the productive power of the British Empire which exists among the upper and middle classes in England would be ludicrous if it were not so deplorable. The loyalty and devotion of the Colonies, right unto the utmost corners of the earth, admit of no dispute. It is observable on every hand and in every national crisis. The doubt is of the loyalty of the centre of the Empire towards its extremities, through the crass ignorance which exists as to the geographical and political meaning of that Empire. I would annihilate that ignorance, as aforesaid, by putting political, historical, and physical geography in the forefront of our educational system; by lectures from your able men in Canada, or Australia, and South Africa, vivified by lantern slides, and encouraged and endowed by the Mother Country. I would bring all visible means of presentment to bear on the education of childhood, boyhood, and youth in the Motherland.

Let me touch on one further educational factor of Imperialism. The sentiment of patriotism, unlike that of charity, is not equally capable of indefinite intension and extension. The peculiar system of education which finds vogue in England in most of our greatest institutions—the institutions from which are drawn the future leaders of the nation—is, as everyone knows, the barrack system, otherwise called the boarding system. It is not the time or place here to enlarge on the obvious advantages of that system, its unique characteristics, its power of moulding character and developing enterprise. But it has its cramping and confining side—it has a tendency to localise patriotism, to narrow a young man's mental horizon, and to ignore whatever lies outside its immediate survey. Hence the abnormal and gladiatorial devotion to games and comparatively selfish amusements, which absorb, and, in my opinion, not seldom paralyse and stifle wider, more generous, more enlightened—in fine, more Imperial instincts. However much in the field of sports the individual youth may subordinate his own self-regarding impulses to the welfare of the tiny community for which he is exercising his energies, his horizon is not wide enough to bid him rise to a sentiment of self-sacrifice and self-abandonment on behalf of a greater and more abstract ideal—love of Fatherland and loyalty to Empire.

But it is a welcome thing to be able to point to a larger sentiment lately awakened in this direction. There is no doubt that the patriotic spirit in our schools and colleges has, from whatever cause, received a great impetus in the last two years, and that the general principles of an intelligent

defence of our shores from foreign aggression have been taught and construed into terms of scientific training and co-operative action with a rapidity equally surprising and welcome to those who, a few years ago, looked with something more than apprehension on the supineness of the youth of England in all patriotic regards.

'The flannelled fool and muddied oaf,'

though they have not yet received their quietus, have been less rampant lately in our educational institutions, and something like an Imperial instinct, born of increasing knowledge both of the glory and dangers of our vast Empire, has, at least in the more cultured classes, taken the place of apathy, disregard, and ignorance. In hours formerly lavished to an abnormal extent on trivial amusements, and even in hours hitherto devoted to more academically intellectual training, we find young men in our schools and colleges now with arms in their hands, shooting, signalling, scouting, and studying scientifically the art of defensive warfare. This at least is 'a beam in darkness, of which we pray that it may grow.'

Time and your patience will not allow me to touch on more than the fringe of the great educational problems which have to be solved before we can approach in English education to what I venture to call the ideal of Imperial responsibility.

In criticising the old mediæval system of education which prevailed in England till comparatively recent years, and which still has far too great a hold on the more venerable and important institutions of our island home, I would not have you suppose that I am an advocate of a complete, or even approximately complete, basis of utilitarian education. It is an easy charge for those who desire *stare super antiquas vias*, to throw in one's teeth. I have little hesitation in expressing my belief that the time has come (and I speak as one whose training was that of a classical scholar, for I was brought up in the straitest sect of academical Pharisees)—I say I have no hesitation in expressing my belief that the time has come, not only that the study of the two ancient languages should be reduced to one for all except scholastic specialists, but also that both should yield pride of place in our educational system to the claims of English, modern languages, mathematics, natural science, and, not least, manual training, so that our young men should be fitly equipped to put their hand to any work which may confront them amid all the complex problems and critical situations to be found within the world-wide boundaries of the British Empire.

Germany, France, and the United States have been beforehand with us in the working out of such a reformed system of education. I am by no means one of those who believe that we should be wise in copying the methods in their entirety of any of these three peoples in their educational methods. Undoubtedly in all three there has been a more organised connection between the actual teaching given in their respective schools and the industrial, social, and political needs of the respective peoples. But no one nation is exactly like another nation in its temper and genius, and I should be sorry to advocate, for instance, the highly organised system of State education in Germany, under which it could be predicted to a certainty that boys and girls in every secondary or primary school on any given Friday morning should be studying (say) the geographical importance of Natal or the outlines of the coast of Lincolnshire. There must be many educational differences, because the idiosyncrasies of each nation differ from those of another, and I do not think we need ever fear that our intrinsic individuality will be crushed into any Teutonic cast-iron mould or ground down beneath the heel of some bureaucratic educational despotism. But that we ought to change our ways still more than we have, and adopt saner educational models, many searchings

of heart through a long educational career have gradually, but overwhelmingly, convinced me. If we are apt to think, speak, and act Imperially, our education must take form from a strong Imperial sentiment, and must aim at instilling Imperial instincts in the young lives which that education is meant to control and develop.

I have spoken hitherto of this subject mainly from the point of view of secondary education, with which I am the most conversant; not only for that reason, however, but because most of those who are destined to proceed to the distant outlying parts of the British Empire, and, when there, to take prominent parts in the development of that Empire, obtain their educational equipment from the secondary schools of England. It is, therefore, on curricula offered or desiderated in them that I have exclusively dwelt. But I do not blink the fact that the proper educational organisation of our elementary schools, on the one hand, and of our universities on the other, exercises a large influence on the solution of Imperial problems.

On elementary education, however, I do not propose to touch in this address, mainly because I look forward to experts in primary schools directing the thoughts of this Association more directly to them. But I will touch with great brevity on the subject of University education.

Whether Oxford and Cambridge—particularly Oxford—will ever so reform themselves as to contribute largely to such solution remains to be seen. Personally, I look with far greater confidence to the more recently organised universities—those of London, Leeds, Sheffield, Manchester, and the like—to equip men educationally with those moral, physical, and intellectual qualities which are most in requisition in our great dependencies and commonwealths.

Such institutions, from their newness, their eagerness, their freedom from antiquated prejudices and vested interests, are more likely to be counted upon for many years to come to send forth a stream of young men who have learned in the school of hardness to face the difficulties and to adapt themselves to the austere conditions which are inseparable from life in unworked regions and half-discovered continents. And it is at once a hopeful and inspiring thought that the great Dominion of Canada will welcome such to herself as sufficient and efficient citizens of her all but boundless territories, that she will recognise in them 'bone of her bone and flesh of her flesh,' physically, mentally, and morally capable, in company with those of her own sons who have long settled in the land, of extending the borders of the Empire by enlarging its resources, and of lifting, securing, and consolidating thereby the destinies of the Anglo-Saxon race.

There is still one more educational factor on which I would ask attention before I close this address. It is this—the necessity of a closer touch educationally (in the sense of 'academically') between the secondary schools and colleges of the Mother Country and similar institutions in the great Dominion and commonwealths which own her parentage. How this can be effected without great modification of our existing English system it is hard to see. But one point is quite clear. We must give up that part of our system which insists on choking the passage of the student from point to point in his educational career by subjecting him to countless examinations on entrance and throughout his academical course. It would be of incalculable advantage to the Empire at large if an extension of educational intercommunion, such as was inaugurated by the noble benefactions of the late Cecil Rhodes, could be secured throughout the Empire. Undoubtedly examination would be the surest test for determining the question of the admission of a student to the privileges of further education, if such examination could be conducted within a limited geographical area. But it is quite an impossible system if adopted as between the outlying parts of a great empire. The United States of America

have taught us a better way. For instance, in the State of Minnesota, the University has legislated that if and when the Principal of a high school of recognised position certifies that a student has successfully pursued for a specified length of time those studies in that high school that would entitle him to admission to the university, he should be admitted thereto without further delay or hindrance. What a paralysing curse the Charybdis of examination has been to all true learning only those who have suffered from it for thirty years can bear adequate testimony. It would be one of the most fertilising sources from which to secure good and progressive citizens, if instead of admitting within her borders all or any who came of their own spontaneity or from compulsion (leaving their country perchance for their country's good) the Government authorities in the Dominion could get into closer touch with the educational authorities of the Mother Country, who would act as guarantee that the material sent out by the Mother Country should be of an approved and first-rate quality. This might be worked on the American 'accredited school' system, under which the authorities of the school sending the pupil should feel the *maximum* of responsibility in recommending his admission to the academical, or the technical, or the industrial organisations existing in the Dominion.

Since penning the first sentences of the above paragraph last June my eye has been caught by a notice which appeared in the columns of the 'Times' on the 28th day of that month while I was engaged in the very act of correcting the proofs of this address; but I prefer to leave the paragraph written as it stands, as the notice in question is an eloquent commentary on my suggestion of educational intercommunion.

I may, perhaps, be allowed to read the extract from the 'Times' *verbatim*, though it may be familiar to some at least among my audience. It is headed 'International Interchange of Students—a New Movement.'

'We have received,' says the 'Times,' 'the following interesting particulars of a new educational movement to provide for the interchange of University students among the English-speaking peoples:—

'The object is to provide opportunities for as many as possible of the educated youth of the United Kingdom, Canada, and the United States (who, it is reasonable to suppose, will become leaders in thought, action, civic and national government in the future) to obtain some real insight into the life, customs, and progress of other nations at a time when their own opinions are forming, with a *minimum* of inconvenience to their academic work and the least possible expense, with a view to broadening their conceptions and rendering them of greater economic and social value, such knowledge being, it is believed, essential for effectual leadership.

. . . .

'The additional objects of the movement are to increase the value and efficiency of, as well as to extend, present University training by the provision of certain Travelling Scholarships for practical observation in other countries under suitable guidance. These scholarships will enable those students to benefit who might otherwise be unable to do so through financial restrictions. It also enables the administration to exercise greater power of direction in the form the travel is to take. In addition to academic qualifications, the selected candidate should be what is popularly known as an "all-round" man; the selection to be along the lines of the Rhodes Scholarships.

'The further objects are to extend the influence of such education indirectly among the men who are not selected as scholars (through intercourse with those who have travelled) by systematic arrangements of the periods' eligibility while they are still undergraduates.

'To promote interest in imperial, international, and domestic relations,

civic and social problems, and to foster a mutual sympathy and understanding imperially and internationally among students.

'To afford technical and industrial students facilities to examine into questions of particular interest to them in manufactures, etc., by observation in other countries and by providing them with introductions to leaders in industrial activity.

'To promote interest in travel as an educational factor among the authorities of Universities, with a view to the possibility of some kind of such training being included in the regular curricula.

'To promote interest in other Universities, their aims and student life, the compulsory physical training, and methods of working their ways through college, for example, being valuable points for investigation.

'To promote international interchange for academic work among English-speaking Universities; and, in the case of the British Empire, to afford facilities for students of one division to gain, under favourable circumstances, information relative to the needs, development, and potentialities of other divisions; and to promote an academic interchange of students among the Universities of the Empire.

'As already indicated, there is a widespread interest in the movements so far as the United Kingdom is concerned; while in Canada and the United States there is also a widespread recognition of the value of the scheme; and although committees have not been actually organised there as in this country, a very large body of the most prominent educationists are strongly in favour of the plan, and have promised their co-operation if the scheme is financed.

'It is proposed to establish two students' travelling bureaux, one in New York and one in London; an American secretary (resident in New York) and a British secretary (resident in London), both of whom shall be college men appointed to afford every facility to any graduate or undergraduate of any University who wishes to visit the United States, Canada, or the United Kingdom for the purpose of obtaining an insight into the student, national, and industrial life of those countries. The bureaux will undertake the work of providing information relating to United States, Canadian, British, and other English-speaking Universities for the use of students, undergraduates, and others. They will also provide information relating to educational tours of any description in English-speaking countries, and the arrangement of tours suitable to the needs of the inquirer with a view to his obtaining the greatest facilities for education with a *minimum* of expense. Furthermore it will be their duty to provide information as to the best places for the study of educational, governmental, industrial, and social problems in the United States, Canada, the United Kingdom, and other parts of the Empire, as well as to provide introductions to leaders in the above-named spheres of activity, besides undertaking the organisation and conduct of special tours for educational purposes, if necessary.

'It is proposed to provide 28 travelling scholarships, 14 of these being available for Universities in the United Kingdom, 10 for Universities in America and four for Universities in Canada. The arrangements will be controlled by general committees, one for the United Kingdom and one for Canada and the United States, unless it is found necessary to inaugurate a separate committee for each of the latter.'

You will observe then that a scheme which I had ventured to suggest as being 'of incalculable advantage to the Empire' had, before I wrote the words quoted, been advocated entirely without my knowledge by a body of influential educational leaders in England, whose names were appended to the notice which I have read; and I need only add that it is quite certain that I am interpreting the sentiments of all here assembled in wishing God-speed to the development of the scheme, which seems likely to prove,

if carried into effect, a great, if not the greatest, educational factor of Imperialism.

But it may be objected here, Is not your own horizon circumscribed? Why should educational ideals be limited, even by so extended a conception as Imperialism? Should not the ultimate aim of all education be, not the federation of one race only, but the federation of the world at large—the brotherhood of man?

I am not concerned to deny that such a lofty conception is the true end of all physical, moral, and mental training.

But if the master mind of a Milton was content to define true education to be 'that which fits a man to perform justly, skilfully and magnanimously all the offices, both public and private, of peace and war,' it may well suffice us if we extend our (at present) too narrow conceptions (the aim of which seems to be the cultivation of a mere island patriotism) to a sphere which has for its end the imperialistic sentiment of a whole race.

It may indeed be well doubted whether a race-sentiment is not an ultimate factor beyond which it is impossible in an imperfect world to go. Universal philanthropy in its most catholic sense is a sentiment which the limited conditions of the earth's surface seem to render impossible. As long as men's ambitions are an unlimited quantity, and as long as the habitable globe remains, as it ever must remain, a limited quantity, so long will the populations of the world be continually liable to shifting movements and frequent dislocations. Practical educationists, then, must inevitably confine the scientific consideration of aims and methods in education to the development of the highest interests of their race rather than of mankind at large.

And that being so, the last point on which I would insist in dealing with the educational factors of Imperialism is to emphasise the importance of what the educationists of the United States call 'civics' as the binding power which should fasten together all the separate educational faggots in any Imperial scheme of education—the duty of personal service to the State, the positive obligation which makes us all members incorporate in one Imperial system. In our love of individual freedom, in our jealousy of interference with our individual liberty of action, in our insular disregard and depreciation of intellectual forces working in our sister communities beyond the seas, we have lost sight of this civic responsibility which has ever lain on our shoulders and from which we can never dissociate ourselves, so long as our Empire remains as part of our ancestral heritage.

It is this positive duty towards each other and our race beyond the seas which those who live in our island home have been slow in realising, and it has been a real blot on our educational system that such ideas as Imperial responsibility and Imperial necessities have not been inculcated in the young people in our schools and colleges. As an illustration, I may observe that it has been even debated and doubted in some responsible quarters in England, whether the Union Jack should wave over our educational institutions on the days of national festivity and national observance.

To sum up. By these, and other kindred means, I would urge a closer educational touch between the Mother Country and the Empire at large.

Long ago a great Minister was able to say: 'Our hold of the Colonies is in the close affection which grows from common names, from kindred blood, and from similar privileges. These are ties which, though light as air, are strong as links of iron.'

But times have changed. To-day we are confronted with the problems of a vast and complicated Empire—great commonwealths, great dominions, sundered from each other by long seas and half a world, and however closely science has geographically brought them together, we cannot in soul and sympathy, nor ultimately in destiny, remain attached, affiliated as mother and children should be, unless we grapple to each other and understand each

other in the greatest of all interests—the educational training which we give to our children in the one part of our Empire, to make them suitable citizens in another.

In suggesting reforms and modifications in which this educational unity may best be expressed, forgive me if I have but touched, and touched inadequately, on the fringe of a great subject, the transcendent importance of which it requires no elaboration of mine to impress on the earnest attention of the people of this great Dominion—which great Dominion may I be allowed to salute, without flattery or favour, as the most favoured by natural beauty and by virgin wealth of all the children of our common Motherland? May I salute her in terms which formed the old toast with which the two greatest of our English public schools, Winchester and Eton, pledged each other when we met in our annual cricket contest: *Mater pulchra, filia pulchrior!*

The following Papers were then read:—

1. *Discussion on Moral Instruction in Schools.*

(i) *Moral Education in Schools. By* Professor L. P. JACKS.

The demand for moral teaching has arisen, in the first instance, from the obvious consideration that the spread of knowledge through general education is socially dangerous when unaccompanied by moral advance. The demand has been greatly reinforced by the growth of the Imperial idea, which is awakening the national conscience and confronting the individual citizen with enlarged responsibilities. The moral needs of the Empire are such as to constitute a demand for 'super-men.' Efficiency is the word generally employed to express this fact, but 'efficiency' means in this connection not merely technical knowledge in trade and courage in war, but moral qualities of a higher order still. The relations in which the Empire stands to its powerful neighbours demand from its citizens magnanimity and consideration for the rights of others; while the problem of subject races suggests the need of a highly developed humanitarian spirit.

Schoolmasters have been among the first to feel the pressure of these new demands, and the result is to be seen in reforms which are taking place in the Universities, in public schools, and in primary education. In each case the object seems to be the training of character on lines more in harmony with the vast responsibilities of the Empire. The effort is being made to develop by various means the heroic element in the temper of the community. Among the means employed the love of one's country has a chief place. The Empire is being shown as an object of such commanding worth in the world's history that the boy may come to regard it as demanding his self-devotion.

The virtues cannot be imparted one by one to young minds; nor should morality be made one among a number of set subjects. What is needed is the idea of an 'end' which by becoming a principle co-ordinates the purposes of life. This is supplied in all teaching which promotes loyalty to the State, and the conditions of the Empire make the present highly favourable for a vigorous enforcement of this principle. On the other hand, all attempts to teach the virtues departmentally will probably fail to produce moral action when the subject of such teaching is confronted with the actualities of life. Morality in education is rather the name of a method, which should dominate the teaching of all subjects, than an independent subject in isolation from the rest.

A further mistake is that of supposing that the virtues can be taught to the young according to a fixed pattern. The attempt to do so leads inevitably to reaction against the idea of morality; and it has to be

remembered that the value of all teaching is measured by the kind of reaction it provokes in the mind of the taught. In this lies the greatest danger of the moral teacher, inasmuch as he cannot control the reaction of his pupils' minds. He may, however, put a wise trust in the sanity of Nature. His task is to explain the truths of their environment to young minds in such a light that the facts themselves when so explained become incentives to moral action. Thus certain facts of geography become morally stimulating when they are presented as *human* facts. In all this the teacher has the warrant of the philosophical principle that the 'Real is the Ideal.' No fact is truly explained until some element of ideal worth has been shown to exist in it. To show this is moral education. Direct exposition of the moral law is valuable only when it points to a field of exercise where its principles are waiting to be realised.

The demand for moral education has an unwelcome aspect in so far as it may be thought to proceed from parents who are anxious to escape from responsibility. The school can never replace the home in the matter of moral teaching. It would be well, therefore, if professional teachers were to imitate the methods of the Japanese by giving a large place in ethics to the strengthening of the family tie. This is enough to suggest that the problem of moral education is as much the concern of women as of men.

(ii) *The Evidences of Moral Education.* *By* Hugh Richardson.

Much interest has been roused in England by the First International Moral Education Congress, which met in London in 1908. The papers read express the ideals of the authors and the means by which they think those ideals might be attained.

There is, however, extraordinary little evidence at to what results have actually been produced ; still less is there any evidence as to which processes have produced which results. This weakness of evidence is in marked contrast with the stringency usually demanded in scientific investigations.

It was suggested that useful work might be done by Section L in criticising alleged results of special methods in moral education, and in exacting much stricter standards of evidence.

Ideals and enthusiasm are invaluable in education. But enthusiastic idealists are not always the coolest critics of their own labours. The workings of the human mind are open to scientific inquiry. Common phenomena and accepted opinions have often repaid severe examination.

---

2. *Exhibit of School Drawings illustrative of English Life.* *By* F. S. Marvin.

FRIDAY, AUGUST 27.

The following Papers and Report were read:—

1. *The Aims of MacDonald College.* *By* Principal J. W. Robertson, *C.M.G., LL.D.*

We in Canada have problems to solve which are peculiar to our community ; problems due to our youth, our wealth, our great stretch of territory, for we are continent wide. By education we hope to solve our problems, and MacDonald College has been provided by the generosity of Sir W. A.

MacDonald as an experiment and illustration in education for the betterment of rural life in Canada. We seek to shift the emphasis from training for letters to training for life. In part the college has grown out of the school garden movement, in part out of the manual training work which is being given through Canada under the leadership of English teachers. In part it has grown out of the desire for educational leadership in face of the need for training the children so as to fit them for rural life.

In the college we train and instruct young men and women for the three fundamental mothering occupations of a young people—first, farming; secondly, home making; thirdly, the teaching of the children. We carry on our work in each of these three fields in close co-ordination. It is not technical education that we aim at putting in the schools—the word technical has a catchy quality and often covers a multitude of shams. What we seek to do is to so readjust the work of the schools that it will have a bearing on the life interests, the opportunities, and the occupations of the rural districts. From the courses of study in many rural schools to-day one could not gather that the parents of the children had any concern with the soil, with crops, or with animals.

Our school course begins with nature study. We are a part of nature; our lives follow natural processes under natural laws. A study of nature lies at the beginning of all true education; through it we can train the children to observe, to investigate, to think, and to understand, and at the same time they are doing things and forming habits of work. Moreover, nature study deals with facts and principles on which systematic study of agriculture must be based.

To nature study we add manual work both for boys and girls, as much for the mental qualities it gives as for the co-ordination and ready co-operation of hand and eye. Here is something on which the student can decide for himself whether it be well or ill done, something that does not need to be assessed by the master's blue pencil, something in which consequences can be clearly traced from causes; ill-made work will not stand. Through such work the pupil learns self-reliance, learns the inevitability of consequences, learns to work to satisfy himself. As an educational subject it only falls short of nature study in that it does not deal with living material.

Finally, we teach the domestic sciences, the art of home-making, necessary and fundamental everywhere, but nowhere more than in the haste and struggle of a young community absorbed in the pursuit of material good.

For the bare maintenance of human life there is need for practical education, much more for the maintenance of our institutions and means of culture. Our teachers must be more than teachers of letters, they must be teachers of men. They must have sympathy, insight, knowledge, energy, enthusiasm, and unselfishness. Under such teachers alone can national safety and progress in all worthy ways be secured.

---

2. *Practical Studies in Elementary Schools. By* W. M. Heller, *B.Sc.*

---

3. *Manual Instruction in Elementary Schools. By* Walter Sargent.

Manual work is winning recognition as a necessary factor in elementary education. First, on the ground that it is essential to general educational development and valuable alike to the artisan and the scholar. Secondly, because it can be so presented as directly to promote industrial efficiency.

The most important arguments for manual work as a cultural subject may be summed up as follows:—

It insures a proper balance of motor and intellectual activity, to the advantage of both; it develops ability to express ideas in material form;

it brings the tonic effect of dealing with the unvarying laws of matter and being compelled to face the obvious fitness or unfitness of the visible results; it awakens the healthy pleasure of shaping material to a predetermined form by patience, foresight, and skill.

So much progress has been made with manual work as a cultural subject that the author left that phase in order to consider the question whether manual work for the purpose of industrial education should be given any place in elementary schools or not.

The fact is significant that in many localities 80 per cent. of the pupils leave at or before the close of the elementary course. These children drift into unskilled occupations, taking whatever work pays best. They are likely to spend two important years in employment which awakens no industrial interests and offers no vocational outlook.

Should not elementary schools provide, in an optional course, training planned definitely to promote industrial efficiency and awaken industrial interests, even if this necessitates work which involves a utilitarian test of the product? It was urged for these 80 per cent. that the elementary school, from which they go directly into industry, should as compensation give them only cultural studies. No sharp definition exists, however, between cultural and industrial education. Most of the activities which raise men from savagery involved a utilitarian test of their results. 'Utilitarian' is a word the meaning of which becomes more inclusive with advancing civilisation.

Experiments with an optional course in which pupils, during one hour each day, made boxes, portfolios, &c., in quantity for the city, have been tried, and show the following results:—

1. Interest in economy of material and time.
2. A willingness to contribute the product to the city, showing that the motive of ownership of the results is not necessary to interest.
3. No loss of thoroughness in other school subjects.
4. Increased efficiency in planning and handling material.
5. Interest in and attraction to more complete industrial courses.

Some of the pupils who leave school at fourteen years of age to enter a shop instead of a high school do so because of financial stress. Co-operation between high school and shop, which allows half time in each, promises to meet many of these cases. A larger number leave because they and their parents feel that work is more worth while. The influence of well-planned industrial courses will tend to keep these pupils to the end of the elementary course and interest them to enter high schools equipped with similar courses.

---

4. *London Trade Schools.* *By* C. W. Kimmins, *M.A.*, *D.Sc.*

The problem of problems in London and elsewhere is to prevent children of fourteen years of age drifting into unskilled labour in which there is no element of permanence. The difficulty is increased by the decay and gradual disappearance of the apprenticeship system and the altered conditions of employment in workshops which make them unsuitable places for the training of craftsmen.

An elaborate scheme of junior, intermediate, and senior scholarships established by the London County Council makes ample provision for the brilliant children of the London elementary schools. The really capable child, even of the poorest parents, may reach the highest position by means of the scholarship ladder, passing at the age of eleven years into the secondary school, and thence by means of scholarships at the age of nineteen to the university or higher technical school. Provision is also made for the transference of children who do not reach scholarship standard to pass on to a higher form of elementary school in which a special bias may be given in training for commercial or industrial life in a course of instruction extending for a year or two beyond the age of compulsory attendance.

The Trade School, however, is of a very special type for children who have to enter upon their life's work at the age of sixteen or seventeen, and who have already decided upon the trade they wish to enter. The age of entry into the trade school coincides approximately with that at which the boy or girl normally leaves the elementary school, viz., thirteen or fourteen years of age, and the course of instruction lasts for two or three years.

In London the boy or girl of fourteen who is physically strong and has received a fairly good education has no difficulty whatever in obtaining employment at a rate of remuneration which appears liberal for a child of this age. The consequence is that in the elementary school the vast majority of the children leave immediately they reach the age of fourteen and become wage-earners. In order to keep children at school above the compulsory age for any definite period it is absolutely necessary not only to give them free education, but, in addition, maintenance scholarships which will recoup the parents to a certain extent for the loss of the earnings of the children.

The scholarships for trade schools for boys extending over a period of three years are generally of the value of 6*l*. for the first, 10*l*. for the second, and 15*l*. for the third year. The trade schools for girls generally have a two years' course, and the value of the scholarships is 8*l*. for the first and 12*l*. for the second year. Unsuccessful candidates who do not obtain scholarships may be awarded free places. For other pupils a low fee of generally 10*s*. a term is charged.

No candidate is eligible for a scholarship whose parents or guardians have an income which exceeds 160*l*. a year from all sources.

The special features of the London trade schools are:—

(1) The assistance given in the direction of the trade teaching by consultative committees of business men and women engaged in the particular trades for the training in which the school provides.

(2) The appointment of After-Care Committees, the members of which interest themselves in the scholars and advise them with regard to employment at the conclusion of the school course, and afterwards see that the conditions of their employment are satisfactory.

(3) The continuance of the general education of the pupils, only about one-half to two-thirds of the school time being given to actual workshop instruction.

(4) The prominence given to art instruction, not only in the technical requirements for the particular trade, but for the general development of a high standard of taste.

(5) The employment of teachers who have attained distinction as practical workers, and who approximate the instruction as far as possible to workshop conditions.

(6) The holding of exhibitions of students' work to which employers are invited and at which offers are frequently made for the employment of students.

Trade schools for boys have been established in engineering, silversmithing, bookbinding, furniture and cabinet making, carriage building, art wood carving, and various branches of the building trades. The trades for which schools have been established for girls are trade dressmaking, laundry work, upholstery, ladies' tailoring, waistcoat making, corset making, millinery, designing and making ready-made clothing, and photography.

The development of trade schools in London is proceeding rapidly. The competition for the scholarships is becoming keener every year, and the work of the students is finding increasing favour with employers. No difficulty is experienced in finding suitable employment for boys and girls who have passed through the schools successfully.

5. *University Policy.* *By* Dean F. F. Wesbrook, *M.A.*

The author referred to the beginning of the University of Manitoba, and paid a tribute to the heroic, self-sacrificing, and unremitting labour of the pioneers in college education at a period in the development of the province when most communities provide only for urgent material needs. He deplored the failure of the province to follow up the initial activity in university matters in a manner comparable to the material progress of the province.

The different types of universities were discussed, and it was assumed that all universities should not only accumulate and dispense knowledge, but that Federal, State, or Provincial universities should specialise in the application of culture and science to the betterment of the whole people and the logical conservation and development of natural resources.

Under these circumstances, the development of the universities of Western Canada and the newer States of the Union should have many, if not most, of their problems in common, and might perhaps better emulate the provincial and newer British universities than those of Oxford and Cambridge or of Harvard and Yale.

The impossibility of separating absolutely the accumulation of knowledge for its own sake from research which might be immediately applicable to human betterment and the practical things of life was pointed out.

The magnificent support given by certain of the State universities such as Wisconsin, Minnesota, Illinois, Michigan, Iowa, and others, was mentioned, and a number of ways in which Wisconsin and Minnesota were able directly to benefit their people were discussed in detail, as illustrating some of the functions of a State university in the endeavour to make it an experimental arm of the Government service and a leading force for the scientific improvement of social and economic conditions.

The importance of having all departments of university activity in close contact and sympathy was magnified, in order that the best possible team work might result. This means large ideas of expenditure in the first place, the provision of a sufficient site, and perfect co-ordination throughout all departments at all times.

Organisation was not discussed in detail, except to point out the very great difference between the democratic form of government at Oxford and Cambridge, whereby the alumni of the institution have complete control, as contrasted with that of the State universities of the United States, where the Government controls the institution entirely. It seemed to the speaker that alumni representation need not be insisted upon, since if the university fulfils its function of bettering the citizens, as a natural sequence, the alumni will, within a relatively short time, be the natural leaders in the community.

This means adequate financial provision for all the newer universities, where work in all departments must be initiated and maintained. The millions of dollars appropriated as endowment and for maintenance of the State universities was gone into somewhat in detail, and the point was very strongly made that State universities need not be divorced from the acceptance of private gifts. It was urged, however, that in the acceptance of private donations the conditions imposed be as flexible as possible; otherwise, in later years it might be found that gifts were not only of diminishing value to the university, but might be found to be actually embarrassing.

Reference was made to the work and reports of the Carnegie Foundation, and the hope was expressed that through careful study of all of the universities of this country and Europe, by a system of carefully standardised inspection, results might be tabulated which would enable the universities to see their deficiencies and correct faults.

The magnificent work of the American Medical Association, through its

Council on Medical Education was referred to as illustrating the value of inspection and published reports.

In conclusion, the author congratulated the province of Manitoba on the work of the present university staff, and begged that they might receive adequate support. It was stated that the benefit accruing to Manitoba was not due to her provision for university development, but rather to the superhuman efforts of a few men, who are wearing themselves out for a province which has been slow to see her own needs. These men should not be allowed to wear themselves out entirely in routine teaching and developmental lines, with little in the way of opportunities for creation except those seized by them at the expense of their own health and welfare. Pioneers bring with them the civilisation of the older countries and are strenuously endeavouring to utilise the wisdom of their fathers and to avoid unnecessary complications and mechanisms. At best the universities must begin with a few years' handicap, but in these days of rapid transit and instantaneous communication it does not take long to convert natural resources into available capital, and the cultural and historical handicap will be found to be a rapidly diminishing one, for which even in the earlier years there may be some compensation in the absence of embarrassing precedent.

The Manitoba authorities were urged to expend at this time large sums of money as a good investment, which will be returned many times over in the next few years of development.

---

6. *The Activities of the State University. By* Dr. W. A. McIntyre.

The ends to be attained by the State university are primarily social. Through it the life of the people is to be quickened and enriched. Its aim is not 'culture for its own sake,' but 'culture for the sake of humanity.' Its objective must be not mere scholarship, but life.

The means to be employed for the attainment of its ends are a central College of Arts, Science, and Literature, and a series of technical schools suited to local needs.

The subjects emphasised in the College of Arts and Science will vary with time and locality. In western life we require to emphasise at the present time social science, language, art; the first because our problems are mainly social, the second because we live through getting and giving thought, and the third because there is danger of over-intellectualisation and sterilisation of the feelings and will. The study of an ancient language should not be compulsory. It will debar too many worthy students.

The technical schools must be established by design, and not because of the importunity of those who wish to create a close preserve. There is a principle of selection. As the great activities of a people are expressed by such terms as production, transportation, exchange, education, legislation, protection, schools should be established to direct effort in all lines indicated by these words. There will therefore be schools of agriculture, mining, fisheries, forestry, &c., and schools corresponding to the leading industries of the State. These will be the first to receive willing recognition. There should also be a school in which the principles of transportation are set forth. We cannot for ever be governed by commissions who have to learn their duties after appointment to office. Then there must be a commercial school. The professional schools must be extended to include the profession of most importance to the State, namely, education. A system of elementary education cannot stand alone. It must be directed by those who see the end from the beginning. Then there must be a school in which the elements of criminology may be taught.

This outline is but suggestive. No mention has been made of physical

and moral education, of libraries and dormitories, and of original research, but these are all important, for the university must attend to everything that affects life. The majority of students get more from association than from class teaching.

The student at a university has a right to expect not only that his knowledge will be increased, but that he will enter into a larger, fuller life. The State has a right to expect that every calling—even the humblest—will receive benefit from an institution it creates and supports. If not, wherefore should the support be given?

MONDAY, AUGUST 30.

Joint Discussion with Section E on Geographical Teaching.—See p. 532.

The following Papers were then read:—

1. *Practical Work in Evening Schools. By* W. HEWITT, *B.Sc.*

The evening school has a distinct and well-recognised place in the existing educational system in England. The special character of its work is determined by the fact that the large majority of students have already entered upon some definite daily occupation and require a training which will give them that broader knowledge and intellectual understanding of their trade or profession which modern industrial conditions do not provide. The desire of many students to confine their attention to a narrow range of specialised technical knowledge has to be overcome by seeking, through the medium of the materials, machinery, and processes of their trade, to arouse an interest in the underlying principles and in the necessary mathematical, geometrical, and experimental discipline. The recent general introduction of systematic courses of work into the evening school system is tending to bring about a better co-ordination of these necessary intellectual methods with the purely professional or mechanical instruction.

For the younger industrial students a course of practical work should include (*a*) simple experimental work in mechanics, physics, and chemistry; (*b*) measurement and drawing to scale with instruments; (*c*) practical exercises in the proper and intelligent use of the tools and simpler machines connected with the trade—each of these sections being utilised to suggest direct exercises in calculation, graphical representation, and clear literary statement. For older students who have a greater practical knowledge of their craft a different course is necessary—introducing and explaining modern developments in machines and processes, explanation of the causes of successful and unsuccessful operations, and, where possible, experimental exercises in testing the strength and character of materials or the results obtained from a machine or piece of practical apparatus arranged for experimental purposes.

In all cases the interest of the student is to be sought by approaching the subject through familiar trade details or phenomena, and letting the necessary mathematical, graphical, or scientific developments arise naturally therefrom. The practical handicraft exercises should be selected so as to combine accurate work to drawing and scale (including, where necessary, geometrical projection or development), and, when possible, leading to the production of an object which embodies a scientific principle associated with the theoretical instruction of the lecture-room. The apparatus for experimental work should be on a scale large enough to be commensurable with actual workshop conditions, and appealing to the student as leading to results as applicable in the workshops as in the laboratory.

---

2. *Nature Study in Secondary Schools.*
By Miss LILIAN J. CLARKE, *B.Sc.*

TUESDAY, AUGUST 31.

The following Papers were read :—

1. *Education and Experimental Psychology.*
By Professor HUGO MÜNSTERBERG.

There is a striking contrast between the attitude of the British and the American educators towards psychology. In England psychology is neglected in the schools; in America its value is over-estimated. This neglect causes the means of education to remain old-fashioned and clumsy instead of profiting from the progress of science, just as if the farmers were to refuse the help of scientific chemistry. On the other hand, the danger of over-estimation is not less grave. The American educator, who wants to subordinate the whole education to scientific psychology, ignores the fundamental fact that a science can give us only the means, but never the aims. Not psychology, but ethics, must show us the goal before science can teach us how to reach it. The psychologist may show how the pupil's mind imitates, but he can never decide what is worthy of imitation. In the same way the psychologist can easily find the ways to hold the attention of the child, but cannot decide which kind of attention is desirable. Anything which is loud and shining and entertaining may attract the attention, and yet inquiry into the true aims of education will convince us that it is ruinous to turn the attention to the interesting material instead of learning to attend to that which demands effort.

Moreover, the psychological attitude demands an analysis of the personality; the child is looked on as a combination of mental elements, in the same way as the physicist looks on the physical thing as a combination of atoms. But that produces in the teacher a tendency to inhibit those emotional responses which refer to the pupil as a real unified personality. Yet tact and sympathy, and love and interest are still more important in the schoolroom than the scientific understanding of the child.

But if these dangers are well understood, there cannot be any doubt that the knowledge of experimental psychology ought to be at the disposal of the teacher as much as experimental physics is at the disposal of the bridge-builder and engineer. This is the more true since in recent years the work of the psychologist has turned directly to the pedagogical problems. The author gave a description of experiments from his own psychological laboratory in Harvard University, all of which involved suggestions for new methods of instruction. They referred especially to the psychology of memory, attention, imagination, perception, and will, and to the psychology of reading, writing, and arithmetic.

2. *Discussion on Education as a Preparation for Agricultural Life in Canada, with special reference to Schoolboys from the Mother Country. Opened by the* Rev. Dr. H. B. GRAY.

(i) *Agricultural Courses in High Schools. By* S. E. LANG.

The severest critics of our too bookish education are those connected with the agricultural interest. Many devices have been suggested with a view to giving an agricultural bias to our elementary education. An effort is now being made to give the teachers such an interest in agriculture as may influence their teaching in our rural schools. The

place, however, for serious work is in the high school. A course in agriculture at that point would form a much needed connecting-link between the rural school and the agricultural college.

Agricultural high schools have been recently established in a few of the States and in certain provinces. Some of these are independent high schools, and some are in the form of courses running parallel with existing courses. Georgia has made more generous provision than any other State, having established an agricultural high school in every one of the fifteen Congressional districts, and set aside for their support the proceeds of a tax on fertilisers. Short courses have been established in six colleges in Ontario.

The author considers that agricultural courses should be established in the provincial high schools. The chief difficulty will be that of securing teachers. The regular science course conducted by the regular high school teacher will not serve the needs of the student of agriculture. Unless very happily constituted, specialists in pure science are apt to lose touch with the working-day world. A study of insects simply as evolutionary forms is one thing; a study of insects in relation to food plants is another. The teacher of agriculture cannot afford for a moment to forget the principle which must govern the management of these studies, namely, the social aspect of human activities. The principle suggests that it is far better to study the food plants in relation to food supply and their structure and growth with a view to their improvement, than to discuss their relationships abstractly and describe the facts of reproduction and growth with no practical end in view.

A course could easily be arranged quite as strong and solid, quite as educationally useful, and quite as satisfactory on the side of general culture as any of the courses now established. It must be strong on the practical side, but it need not be costly. The teacher can readily make arrangements for stock-judging and the study of machinery. For the purpose of experimentation with plant growth a quarter of an acre should serve as well as a quarter section. The teacher must be a man of insight, courage, and inventiveness; must create his own methods; and, above all, be alive to the needs of the community. Left entirely to itself, and out of touch with the community, an apostolic succession of schoolmasters would presently develop a ritual and routine of Egyptian formalism. The course and the teacher must command the confidence of the farmers, and the course should lead the student directly into the university.

(ii) *Household Science Teaching in Canada, with particular reference to Advanced Work in Ontario. By* Miss C. C. Benson.

The work on household science leads directly to preparation for family life, and strives to remedy the defects of its disintegration, and is therefore of importance for all countries.

The classes in elementary schools are taken in connection with other classes.

The Guelph Home-makers' courses are offered to farmers' daughters, helping to train them to make the best of and to improve home conditions, and in both Guelph and Toronto courses are offered as preparation for teachers of household science. These and similar courses serve as preparation for the work of matrons and housekeepers in hospitals, schools, and public institutions.

The University of Toronto offers a four years' course, leading to the degree of Bachelor of Arts, which is quite similar to the other science courses there given, allowing, however, special study of household problems, as a chemistry course would allow a special study of some branch of that subject.

(iii) *Colonisation of English Women in Western Canada.* *By* Mrs. Hopkinson.

There are many girls now training in England who would be most admirably fitted to settle here. Girls with good school education, who in their later educational years do not turn to the women's colleges of a purely educational character with a view of ultimately becoming teachers, or to other indoor occupations, but by temperament and strong desire are led to seek outdoor pursuits in the hope and certainty of being able thus and more agreeably to themselves to earn their own living.

Opportunities are given for such outdoor training at various institutions in England, the one I am more nearly connected with being the Swanley Horticultural College in Kent for girls, which in 1891 threw its doors open to women, and ultimately became exclusively a women's college. Here are taught horticulture in all its branches, fruit culture, bee-keeping, dairy work, poultry-keeping, market gardening, sale of produce, landscape gardening, and nature study. And at the colonial branch of this college all the various domestic pursuits in simple form are taught, to fit the girls for colonial life. I read in the admirable paper the Principal of Swanley College lately gave at the International Union of Women Workers' meeting in this country, that of Swanley students holding posts out of England one is a head gardener in Canada and one in Nova Scotia. Another had charge of a few large school gardens in a town in South Africa, which she has laid out and planted. One is an apiarist at a State farm in New Zealand. Two are lecturers on gardening schools in Germany. Another has started a small horticultural school in Switzerland, and yet another a similar one in Sweden.

We know that not a few of those still at home are fired with enthusiasm, and are prepared to try their future here and help with the development of the country; even prepared to introduce a little capital if suitable settlements are established—say, on a moderate acreage of land ready for cultivation, and so in a condition to return income speedily—with a dwelling-house on the land; a settlement, in short, to which they could come for some preliminary training in local conditions, bringing with them their English knowledge of the outdoor occupations of which I have spoken. Thence they could pass on, possibly to gardens of their own, or to posts as home helps, with the trained outdoor knowledge, which must be indeed useful to anyone in this country of growth and fertility. Such settlements or training centres would also form a home—essential to those with few friends in a new country—to which they could return in holiday time or in case of loss or of interrupted occupation, the conditions of such return to be made very easy.

I know in England we could send out the right women and suitable lady superintendents to manage such homes. We believe that settlements like these would help both countries by introducing the right girls here and relieving the pressure over there.

I throw out these suggestions in case any strong hand from here will be held out to us to help in the expansion of this work. We would do our utmost to further it in England, and you will see we have made a hopeful beginning here.

(iv) *Practical Work in Higher Education.* *By* Miss H. D. Oakley.

The subject under discussion, that of the movement for introducing more practical outlook into higher education, seems to me, in spite of its utilitarian appearance, eminently philosophical. For throughout all the schemes it is the end, the goal, which is directing and regulating the means. With reference to the disintegration of home life, to which the President referred, the home science and economic scheme is an effort to

combat this in the way that belongs to the present age, *i.e.*, by expressing the value of home life in scientific terms. In the course about which I know most, that of King's College for Women, one means taken to secure our ends is by the place given to economics. The students are constantly reminded that the sciences underlying home life must not be studied in isolation, but in relation to the whole of modern life. Biology is also made a fundamental subject for kindred reasons. I have no time in which to show how the courses in England differ from those described by Miss Benson. In the main the ends are the same. Perhaps the English students are preparing for a greater variety of careers than those who take up these subjects here, *e.g.*, social settlement work, health visiting, social work in rural villages, as well as for the teaching of domestic science in a more scientific way than it has been taught up to the present.

---

3. *The Organisation of Education in Manitoba. By* R. FLETCHER.

EVENING DISCOURSES.

THURSDAY, AUGUST 26.

The Seven Styles of Crystal Architecture.

By Dr. A. E. H. Tutton, *F.R.S.*

The proverbial importance of the number seven is once more illustrated in regard to the systems of symmetry exhibited by solid matter in its most perfectly organised form, the crystalline. For there are seven such systems or styles of architecture of crystals, just as there are seven distinct notes in the musical octave, and seven chemical elements in the octave or period of Newlands and Mendeléeff, the eighth or octaval note or element being but a repetition on a higher scale of the first.

A crystal appeals to us in two distinct ways, first compelling our admiration for its beautifully regular exterior shape, and next impressing us with the fact of its internal homogeneity, expressed in the cases of transparent crystals by its perfect limpidity, and the obvious similarity throughout its internal structure. As it is with human nature at its best, the external appearance is but the expression of the internal character.

The purpose of this discourse is not so much to dilate upon the seven geometrical systems of crystals, as to show how they are occasioned by differences in the internal structure, and to demonstrate this internal structure in an ocular manner, unfolding at the same time some interesting phases of recent investigation.

In order to remind ourselves of the seven crystal systems, a series of seven lantern slides will be exhibited, prepared from photographs of real small crystals, taken by the lecturer with the aid of the microscope and camera while in the act of formation on a microscope slide. To the Greeks, whose wonderfully perfect knowledge of geometry we are ever admiring, the cube was the emblem of perfection, for like the Holy City, lying 'foursquare,' described in the inimitable language of the book of Revelation, 'The length and the breadth and the height of it are equal.' Moreover, even when we have added that all the angles are right angles, these are not the only perfections of the cube, for they carry with them, when the internal structure is developed to its highest possibility, no less than twenty-two elements (thirteen axes and nine planes) of symmetry.

At the other extreme is the seventh, the triclinic, system, in which the symmetry is at its minimum, neither planes nor axes of symmetry being developed, but merely parallelism of faces, sometimes described as symmetry about a centre, and in which there are no right angles and there is no equality among adjacent edges. Between these two extremes of maximum and minimum symmetry we have the five systems known as the hexagonal, tetragonal, trigonal, rhombic, and monoclinic, possessing respectively, 14, 10, 8, 6, and 2 elements of symmetry. Photographs of real crystals belonging to all these seven respective systems will now be thrown on the screen. All crystals do not possess the full symmetry of their system, each system being subdivisible into classes possessing a definite number of the possible elements. Altogether there are thirty-two such classes, and their definite recognition we owe to the genius of von Lang and Story Maskelyne.

The characteristic property possessed in common by all crystals is that the exterior form consists of and is defined by truly plane faces, inclined, in accordance with one of the thirty-two classes of symmetry, at specific angles which are characteristic of the substance. This has only been proved to be an absolute fact within the last few years, although asserted by Haüy so long ago as the year 1783 ; for the numerous cases of so-called 'isomorphous' salts, the first

of which were discovered by Mitscherlich in the year 1820, were for long believed to be exceptions, and until the year 1890 no actual evidence one way or the other was forthcoming. But it was eventually shown that the crystals of the members of an isomorphous series did differ, both in their angles and in all their other crystallographic and physical properties, although in the cases of the angles the differences were very small. Moreover, the differences were shown to obey a simple but very interesting law—namely, that they were functions of the atomic weight of the chemical elements of the same family group whose interchange gives rise to the series. [A series of lantern slides was next shown to illustrate this law.]

All crystals possess one other obvious property, that of homogeneity, and we now know that it is the character of the homogeneous substance which determines the external form. There are no fewer than 230 different kinds of homogeneous structures, neither more nor less, the elucidation of which we owe to the independent recent labours of Schönflies, von Fedorow, and Barlow. And it is a significant fact that the whole of them fall naturally into the thirty-two classes of crystals, leaving no class unaccounted for. Of these 230 modes of regular repetition in space fourteen are the space-lattices long ago revealed to us by Bravais, and all recent investigation concurs in indicating two facts—first, that it is the space-lattice which determines the crystal system, and second, that it is the arrangement of the chemical molecules which is represented by the space-lattice. Each cell of the space-lattice corresponds to a molecule. The structure is certainly not solid throughout, however, part only being matter, and the rest ether-filled space, the relative proportions and the shape of the material portion being as yet unknown. We limit ourselves, therefore, to considering each molecule as a point, and we draw the lattice as a network of three systems of parallel lines, parallel to the directions of the three principal crystal edges, analogous, according to the system of symmetry, to those of the cube. The points of intersection we consider as those representing the molecules, inasmuch as any point within the limits of the cell may equally well be taken to represent the cell and the molecule, provided the choice is analogously made throughout the structure. [Such a space-lattice, one of the most general, triclinic, form, was shown on the screen.]

It has recently been found possible to determine the relative dimensions of these molecular cells, the distances of separation of the points of the space-lattice, in those cases where we know that the structure is similar, as in isomorphous salts; and the interesting discovery has been made that the 'molecular distance ratios,' as these space-dimensions are called, are functions of the atomic weights of the interchangeable members of the family of chemical elements constituting the series, just as the crystal angles have been shown to be.

We are now able, moreover, to take yet one further step, for the chemical molecules are composed of atoms, and it has been indubitably shown that the atoms occupy definite positions in the crystal. For when we replace, say, the alkali metal in a sulphate or selenate, by another, we observe a marked alteration in the crystal angles and the molecular distance ratio along a particular direction, this direction being the same whichever metals of the group are interchanged; whereas if we replace the sulphur by selenium, a similar kind of alteration occurs, but along a totally different direction. Now we know that the atoms are arranged in the chemical molecule in what is known to chemists as their stereometric arrangement, depending on the maximum satisfaction of their chemical affinities. Hence this important experimental fact of the occupation by the atoms of definite positions in the crystal proves firstly the homogeneous similarity of arrangement of the molecules, and secondly explains why we have classes or subdivisions within the systems. For it is the arrangement of the atoms within the molecule which causes the variations of the degree of symmetry, within the limits prescribed by the system and space-lattice; in other words, which determines the class.

Now obviously any one of the atoms in the molecule may be chosen to represent the latter, and the points thus chosen analogously throughout the structure will constitute the molecular space-lattice. Hence the whole structure may be considered as made up of as many interpenetrating similar space-lattices as there are atoms in the molecule. The crystal structure will thus be dependent on two factors, the space-lattice and the scheme of interpenetration of the space-lattices, the former dominating the style of architecture, the crystal system, and the latter

the vagaries of the style, the crystal class. Sohncke has shown that there are sixty-five such vagaries possible, which he terms regular point systems, and these coincide with sixty-five of the 230 possible modes of partitioning space.

These are the broad simple facts, now proved up to the hilt, which explain the majority of crystal structures, all, in fact, but a very few of the more complicated classes of the thirty-two. For the remaining 165 ways of appropriating space all fall into a very small number of crystal classes. They are of very great interest, however, and involve an entirely new principle, that of 'reflective' or 'mirror-image' symmetry, enantiomorphism as it is technically termed, and include those crystals which possess the remarkable property of rotating the plane of polarised light. These are the cases whose geometrical possibility has been accounted for by the simultaneously independent work of Schönflies, von Fedorow, and Barlow, and to which we were experimentally introduced by the discovery of the right- and left-handed varieties of tartaric acid by Pasteur. The latter has since been followed by the revelation of many similar cases of two forms of the same chemical substance, related crystallographically and structurally like a right-hand to a left-hand glove, and optically differing by the direction in which they rotate a beam of plane polarised light.

With their discovery and explanation the elucidation of the seven styles of crystal architecture and their thirty-two subdivisions becomes *un fait accompli*, and although many difficult problems still confront the crystallographer, problems of vast importance to chemistry, the groundwork is now securely laid, the memorable achievement of the last twenty years. The results, moreover, are in entire accordance with the now well-proved fact that the chemical atom is composed of electronic-corpuscles. For the definite orientation of the atom and its sphere of influence within the molecule and the crystal is thereby accounted for, the motion in the solid state so frequently hitherto attributed to the atom being a myth, such motion relating, in fact, to the corpuscles within the atom.

[The rest of this discourse was devoted to experimentally demonstrating, with the aid of a projection Nicol-prism polariscope of original construction, firstly, the optical behaviour of the simpler kinds of crystal structure, and, secondly, that of the interesting cases of mirror-image symmetry.] Quartz in particular will afford us not only some magnificent phenomena by reason of its right- or left-handed structure, but also a most instructive example, in its repeatedly twinned and all-but-molecularly alternating variety of amethyst, of the phenomenon of 'pseudo-racemism.' For it is the display of this phenomenon which often renders a crystalline inactive substance so difficult to distinguish from a truly 'racemic' substance, which, as in the case of racemic acid itself, the optically inactive variety of tartaric acid, is a truly molecular compound of the right- and left-handed active varieties, the optical activity being neutralised and destroyed by the act of combination.

TUESDAY, AUGUST 31.

Our Food from the Waters. By Professor W. A. HERDMAN, *F.R.S.*

At the last meeting of the British Association in Canada (Toronto, 1897) I was able to lay before Section D a preliminary account of the results of running sea-water through four silk tow-nets of different degrees of fineness continuously day and night during the voyage from Liverpool to Quebec. During the eight days' traverse of the North Atlantic, the nets were emptied and the contents examined morning and evening, so that each such gathering was approximately a twelve-hours' catch, and each day and each night of the voyage was represented by four gatherings.

This method of collecting samples of the surface fauna of the sea in any required quantity per day or hour from an ocean liner going at full speed was suggested to me by Sir John Murray of the *Challenger* Expedition, and was first practised, I believe, by Murray himself in crossing the Atlantic. I have since been able to make similar traverses of several of the great oceans, in addition to the North Atlantic—namely, twice across the Equator and through the South Atlantic, between England and South Africa, and four times through the Mediterranean, the Red Sea, and the Indian Ocean to Ceylon—and no doubt other naturalists have done much the same. The method is simple, effective, and inexpensive; and the gatherings, if taken continuously, give a series of samples amounting to a section through the surface layer of the sea, a certain volume of water being pumped in continuously through the bottom of the ship, and strained through the fine silk nets, the mesh of which may be the two-hundredth of an inch across, before passing out into the sea again. In examining with a microscope such a series of gatherings across an ocean, two facts are brought prominently before the mind: (1) the constant presence of a certain amount of minute living things; (2) the very great variation in the quantity and in the nature of these organisms. [Illustrations showing this were given.]

Such gatherings taken continuously from an ocean liner give, however, information only in regard to the surface fauna and flora of the sea, including many organisms of fundamental importance to man as the immediate or the ultimate food of fishes and whales and other useful animals. [Examples were shown.]

It was therefore a great advance in Planktology when Professor Victor Hensen (1887) introduced his vertical quantitative nets which could be lowered down and drawn up through any required zones of the water. The highly original ideas and the ingenious methods of Hensen and his colleagues of the Kiel School of Planktology—whether all the conclusions which have been drawn from their results be accepted or not—have at the least inaugurated a new epoch in such oceanographic work; and have inspired a large number of disciples, critics, and workers in most civilised countries, with the result that the distribution of minute organisms in the oceans and the fresh waters of the globe are now much more fully known than was the case twenty, or even ten, years ago. But perhaps the dominant feeling on the part of those engaged in this work is that, notwithstanding all this activity in research and the mass of published literature which it has given rise to, much still remains to be done, and that the Planktologist is still face to face with some of the most important unsolved problems of biology.

It is only possible in an address such as this to select a few points for demonstration and for criticism—the latter not with any intention of disparaging the stimulating work that has been done, but rather with the view of emphasising the difficulties, of deprecating premature conclusions, and of advocating more minute and more constant observations.

The fundamental ideas of Hensen were that the Plankton, or assemblage of more or less minute drifting organisms (both animals and plants) in the sea, is uniformly distributed over an area where the physical conditions are approximately the same, and that by taking a comparatively small number of samples it would be possible to calculate the quantity of Plankton contained at the time of observation in a given sea area, and to trace the changes of this Plankton both in space and time. This was a sufficiently grand conception, and it has been of great service to science by stimulating many workers to further research. In order to obtain answers to the problems before him, Hensen devised nets of the finest silk of about 6,000 meshes in the square centimetre, to be hauled up from

the bottom to the surface, and having their constants determined so that it is known what volume of water passes through the net under certain conditions, and yields a certain quantity of Plankton. [Examples of the nets and the methods of working shown.]

Now if this constancy of distribution postulated by Hensen could be relied upon over considerable areas of the sea, far-reaching conclusions, having important bearings upon fisheries questions, might be arrived at; and such have, in fact, been put forward by the Kiel Planktologists and their followers – such as the calculation by Hensen and Apstein that the North Sea in the spring of 1895 contained at least 157 billions of the eggs and larvæ of certain edible fish; and from this figure and the average numbers of eggs produced by the fish, their further computation of the total number of the mature fish population which produced the eggs – a grand conclusion, but one based upon only 158 samples, taken in the proportion of one square metre sampled for each 3,465,968 square metres of sea. Or, again, Hensen's estimation, from 120 samples, of the number of certain kinds of fish eggs in a part of the West Baltic; from which, by comparing with the number [1] of such eggs that would normally be produced by the fish captured in that area, he arrived at the conclusion that the fisherman catches about one-fourth of the total fish population—possibly a correct approximation, though differing considerably from estimates that have been made for the North Sea.

Such generalisations are most attractive, and if it can be established that they are based upon sufficiently reliable data, their practical utility to man in connection with sea-fishery legislation may be very great. But the comparatively small number of the samples, and the observed irregularity in the distribution of the Plankton (containing, for example, the fish eggs) over wide areas, such as the North Sea, leave the impression that further observations are required before such conclusions can be accepted as established.

Of the criticisms that have appeared in Germany, in the United States and elsewhere, the two most fundamental are: (1) That the samples are inadequate; and (2) that there is no such constancy and regularity in distribution as Hensen and some others have supposed. It has been shown by Kofoid, by Lohmann, and by others that there are imperfections in the methods which were not at first realised, and that under some circumstances anything from 50 to 98 per cent. of the more minute organisms of the Plankton may escape capture by the finest silk quantitative nets. The mesh of the silk is $\frac{1}{200}$th inch across, but many of the organisms are only $\frac{1}{3000}$th inch in diameter, and so can readily escape. [Examples shown.]

Other methods have been devised to supplement the Hensen nets, such as the filtering of water pumped up through hose-pipes let down to known depths, and also the microscopic examination in the laboratory of the centrifuged contents of comparatively small samples of water obtained by means of closing water-bottles from various zones in the ocean. But even if deficiencies in the nets be thus made good by supplementary methods, and be allowed for in the calculations, there still remains the second and more fundamental source of error, namely, unequal distribution of the organisms in the water; and in regard to this a large amount of evidence has now been accumulated, since the time when Darwin, during the voyage of the *Beagle*, on March 18, 1832, noticed off the coast of South America vast tracts of water discoloured by the minute floating Alga, *Trichodesmium erythræum*, which is said to have given its name to the Red Sea, and which Captain Cook's sailors in the previous century called 'sea-sawdust.' Many other naturalists since have seen the same pheno-

[1] It is probable that too high a figure was taken for this.

menon, caused both by this and by other organisms. It must be of common occurrence, and is widespread in the oceans, and it will be admitted that a quantitative net hauled vertically through such a Trichodesmium bank would give entirely different results from a haul taken, it might be, only a mile or two away, in water under, so far as can be determined, the same physical conditions, but free from Trichodesmium. [Illustrations shown.]

Nine nations bordering the North-West seas of Europe, some seven or eight years ago, engaged in a joint scheme of biological and hydrographical investigation, mainly in the North Sea, with the declared object of throwing light upon fundamental facts bearing on the economic problems of the fisheries. One important part of their programme was to test the quantity, distribution, and variation of the Plankton by means of periodic observations undertaken four times in the year (February, May, August, and November) at certain fixed points in the sea. Many biologists considered that these periods were too few and the chosen stations too far apart to give reliable results. It is possible that even the original promoters of the scheme would now share that view, and the opinion has recently been published by the American Planktologist, C. A. Kofoid—than whom no one is better entitled, from his own detailed and exact work, to express an authoritative verdict—that certain recent observations ' can but reveal the futility of the Plankton programme of the International Commission for the investigation of the sea. The quarterly examinations of this programme will, doubtless, yield some facts of value, but they are truly inadequate to give any reliable view of the amount and course of Plankton production in the sea.' [1] That is the latest pronouncement on the subject, made by a neighbour of yours to the South, who has probably devoted more time and care to detailed Plankton studies than anyone else on this continent. [Examples were shown of very diversified Plankton hauls from neighbouring localities on the same date, or from the same locality on adjacent days, to illustrate irregularity in distribution.]

It is evident from such results that before we can base far-reaching generalisations upon our Plankton samples, a minute study of the distribution of life in both marine and fresh waters at very frequent intervals throughout the year should be undertaken. Kofoid has made such a minute study of the lakes and streams of Illinois, Marsh of those of Wisconsin, and similar intensive work is now being carried out at several localities in Europe.

Too little attention has been paid in the past to the distribution of many animals *in swarms*, some parts of the sea being crowded and neighbouring parts being destitute of such forms, and this not merely round coasts and in the narrow seas, but also in the open ocean. For example, some species of Copepoda and other small crustacea occur notably in dense crowds, and are not universally distributed. This is true also of some of the Diatoms, and also of larger organisms. Many naturalists have remarked upon the banks of Trichodesmium, of Medusae and Siphonophora, of Salpae, of Pteropods, of Peridinians and of other common constituents of the Plankton. Cleve's classification into Tricho-Plankton (arctic), Styli-Plankton (temperate), and Desmo-Plankton (tropical) depends upon the existence of such vast swarms of particular organisms in masses of water coming into the North Atlantic from different sources.

It is possible that in some parts of the ocean, far from land, the Plankton may be distributed with the uniformity supposed by Hensen. It is important to recognise that at least three classes of locality exist in the sea in relation to distribution of Plankton:—

(1) There are estuaries and coastal waters where there are usually

[1] *Internationale Revue der Hydrobiologie und Hydrographie*, vol. i., p. 846, December 1908.

strong tidal and other local currents, with rapid changes of conditions, and where the Plankton is largely influenced by its proximity to land.

(2) There are considerable sea areas, such as the centre of the North Sea and the centre of the Irish Sea, where the Plankton is removed from coastal conditions, but is influenced by various factors which cause great irregularity in its distribution. These are the localities [1] of the greatest economic importance to man, and to which attention should especially be directed.

(3) There are large oceanic areas in which there may be uniformity of conditions, but it ought to be recognised that such regions are not those in which the Plankton is of most importance to men. The great fisheries of the world, such as those of the North Sea, the cod fishery in Norway, and those on the Newfoundland Banks, are not in mid-ocean, but are in areas round the continents, where the Plankton is irregular in its distribution.

As an example of a locality of the second type, showing seasonal, horizontal, and vertical differences in the distribution of the Plankton, we may take the centre of the Irish Sea, off the south end of the Isle of Man. Here, as in other localities which have been investigated, the Phyto-Plankton is found to increase greatly about the time of the vernal equinox, so as to cause a maximum, largely composed of Diatoms, at a period ranging from the end of March to some time in May—this year to May 28, in the Irish Sea. Towards the end of this period the eggs of most of the edible fishes are hatching as larvæ. [Statistics and diagrams showing this maximum for the last three years were exhibited.]

This Diatom maximum is followed by an increase in the Copepoda (minute crustacea), which lasts for a considerable time during the early summer; and as the fish larvæ and the Copepoda increase there is a rapid falling off in Diatoms. Less marked maxima of both Diatoms and Copepoda may occur again about the time of the autumnal equinox. These two groups—the Diatoms and the Copepoda—are the most important economic constituents in the Plankton. A few examples showing their importance to man may be given: Man eats the oyster and the American clam, and these shell-fish feed upon Diatoms. Man feeds upon the cod, which in its turn may feed on the whiting, and that on the sprat, and the sprat on Copepoda, while the Copepoda feed upon Peridinians and Diatoms; or the cod may feed upon crabs, which in turn eat 'worms,' and these feed upon smaller forms which are nourished by the Diatoms. Or, again, man eats the mackerel, which may feed upon young herring, and these upon Copepoda, and the Copepoda again upon Diatoms. All such chains of food matters from the sea seem to bring one through the Copepoda to the Diatoms, which may be regarded as the ultimate 'producers' of food in the ocean. Thus our living food from the waters of the globe may be said to be the Diatoms and other microscopic organisms as much as the fishes.

Two years ago, at the Leicester meeting of the British Association, I showed that if an intensive study of a small area be made, hauls being taken not once a quarter or once a month, but at the rate of ten or twelve a day, abundant evidence will be obtained as to: (1) variations in the distribution of the organisms, and (2) irregularities in the action of the nets. [Examples shown.] Great care is necessary in order to ensure that hauls intended for comparison are really comparable. Two years' additional work since in the same locality, off the south end of the Isle of Man, has only confirmed these results, viz., that the Plankton is liable to be very unequally distributed over the depths, the localities, and the dates. One net may encounter a swarm of organisms which a neighbouring net escapes, and a sample taken on one day may be very different in quantity from a sample taken under the same conditions next day. If an observer were to take quarterly, or even monthly, samples of the Plankton, he might

[1] See Dakin, *Trans. Biol. Soc. Liverpool*, xxii., p. 544.

obtain very different results according to the date of his visit. For example, on three successive weeks about the end of September he might find evidence for as many different far-reaching views as to the composition of the Plankton in that part of the Irish Sea. Consequently, hauls taken many miles apart and repeated only at intervals of months can scarcely give any sure foundation for calculations as to the population of wide sea areas. It seems, from our present knowledge, that uniform hydrographic conditions do not determine a uniform distribution of Plankton. [Some statistics of hauls shown.]

These conclusions need not lead us to be discouraged as to the ultimate success of scientific methods in solving world-wide Plankton and fisheries problems, but they suggest that it might be wise to secure by detailed local work a firm foundation upon which to build, and to ascertain more accurately the representative value of our samples before we base conclusions upon them.

I do not doubt that in limited, circumscribed areas of water, in the case of organisms that reproduce with great rapidity, the Plankton becomes more uniformly distributed, and a comparatively small number of samples may then be fairly representative of the whole. That is probably more or less the case with fresh-water lakes;[1] and I have noticed it in Port Erin Bay in the case of Diatoms. In spring, and again in autumn, when suitable weather occurs, as it did two years ago at the end of September, the Diatoms may increase enormously, and in such circumstances they seem to be very evenly spread over all parts and to pervade the water to some depth; but that is emphatically *not* the case with the Copepoda and other constituents of the Plankton, and it was not the case even with the Diatoms during the succeeding year.

I have published elsewhere an observation that showed very definite limitation of a large shoal of crab Zoëas, so that none were present in one net while in another adjacent haul they multiplied several times the bulk of the catch and introduced a new animal in enormous numbers. [Diagrams shown.] Had two expeditions taken samples that evening at what might well be considered as the same station, but a few hundred yards apart, they might have arrived at very different conclusions as to the constitution of the Plankton in that part of the ocean.

It is possible to obtain a great deal of interesting information in regard to the 'hylokinesis' of the sea without attempting a numerical accuracy which is not yet attainable. The details of measurement of catches and of computations of organisms become useless, and the exact figures are non-significant, if the hauls from which they are derived are not really comparable with one another and the samples obtained are not adequately representative of nature. If the stations are so far apart and the dates are so distant that the samples represent little more than themselves, if the observations are liable to be affected by any incidental factor which does not apply to the entire area, then the results may be so erroneous as to be useless, or worse than useless, since they may lead to deceptive conclusions. It is obvious that we must make an intensive study of small areas before we draw conclusions in regard to relatively large regions, such as the North Sea or the Atlantic Ocean. Our Plankton methods are not yet accurate enough to permit of conclusions being drawn as to the number of any species in the sea.

The factors causing the seasonal and other variations in the Plankton already pointed out may be grouped under three heads, as follows:—

(1) The sequence of the stages in the normal life history of the different organisms.

[1] See, however, C. Dwight Marsh, in *Trans-Wisconsin Acad. of Sci.*, vol. xiii., and *Wisconsin Geol. and Nat. Hist. Survey*, Bull. xii.

(2) Irregularities introduced by the interactions of the different organisms.

(3) More or less periodic abnormalities in either time or abundance caused by the physical changes in the sea, which may be grouped together as 'weather.' [Illustrated by diagrams.]

These are all obvious factors in the problem, and the constitution of the Plankton from time to time throughout the year must be due to their interaction. The difficulty is to disengage them from one another, so as to determine the action of each separately.

Amongst the physical conditions coming under the third heading, the temperature of the sea is usually given a very prominent place. There is only time to allude here to one aspect of this matter.

It is often said that tropical and sub-tropical seas are relatively poor in Plankton, while the colder Polar regions are rich. In fishing Plankton continuously across the Atlantic it is easy from the collections alone to tell when the ship passes from the warmer Gulf Stream area into the colder Labrador current. This is the reverse of what we find on land, where luxuriant vegetation and abundance of animal life are characteristic of the tropics in contrast to the bare and comparatively lifeless condition of the Arctic regions. Brandt has made the ingenious suggestion that the explanation of this phenomenon is that the higher temperaure in tropical seas favours the action of denitrifying bacteria, which therefore flourish to such an extent in tropical waters as seriously to diminish the supply of nitrogen food and so limit the production of Plankton. Loeb,[1] on the other hand, has recently revived the view of Murray, that the low temperature in Arctic waters so reduces the rate of all metabolic processes, and increases the length of life, that we have in the more abundant Plankton of the colder waters several generations living on side by side, whereas in the Tropics with more rapid metabolism they would have died and disappeared. The temperature of the sea-water, however, appears to have little or no effect in determining the great vernal maximum of Phyto-Plankton.

Considering the facts of photosynthesis, there is much to be said in favour of the view that the development and possibly also the larger movements of the Plankton are influenced by the amount of sunlight, quite apart from any temperature effect.

Bullen[2] showed the correlation in 1903-07 between the mackerel catches in May and the amount of Copepod Plankton in the same sea. The food of these Copepoda has been shown by Dakin to be largely Phyto-Plankton; and Allen has lately[3] correlated the average mackerel catch per boat in May with the hours of sunshine in the previous quarter of the year [curves shown], thus establishing the following connection between the food of man and the weather: Mackerel—Copepoda—Diatoms—Sunshine. One more example of the influence of light may be given. Kofoid has shown that the Plankton of the Illinois River has certain twenty-nine-day pulses, which are apparently related to the lunar phases, the Plankton maxima lagging about six days behind the times of full moon. The light from the sun is said to be 618,000 times as bright as that from the full moon; but the amount of solar energy derived from the moon is sufficient, we are told, appreciably to affect photosynthesis in the Phyto-Plankton. The effectiveness of the moon in this photosynthesis to that of the sun is said to be as two to nine, and, if that is so, Kofoid is probablyjustified in his contention that at the time of full moon the additional light available has a marked effect upon the development of the Phyto-Plankton.

As on land, so in the sea, all animals ultimately depend upon plants for their food. The plants are the producers and the animals the con-

[1] *Darwin and Modern Science* (Cambridge, 1909), p. 247.
[2] *M. B. A. Journ.*, viii. 269.
[3] *Ibid.*, vii. 394.

sumers in nature, and the pastures of the sea, as Sir John Murray pointed out long ago, are no less real and no less necessary than those of the land. Most of the fish which man uses as food spawn in the sea at such a time that the young fry are hatched when the spring Diatoms abound, and the Phyto-Plankton is followed in summer by the Zoo-Plankton (such as Copepoda), upon which the rather larger but still immature food fishes subsist. Consequently the cause of the great vernal maximum of Diatoms is one of the most practical of world problems, and many investigators have dealt with it in recent years. Murray first suggested that the meadows of the sea, like the meadows of the land, start to grow in spring simply as a result of the longer days and the notable increase in sunlight. Brandt has put forward the view that the quantity of Phyto-Plankton in a given layer of surface water is in direct relation to the quantity of nutritive matters dissolved in that layer. Thus the actual quantity present of the substance—carbon, nitrogen, silica, or whatever it may be—that is first used up determines the quantity of the Phyto-Plankton. Nathansohn in a recent paper [1] contends that what Brandt supposes never really happens; that the Phyto-Plankton never exhausts any food constituent, and that it develops just such a rate of reproduction as will compensate for the destruction to which it is subjected. This destruction he holds is due to two causes: currents carrying the Diatoms to unfavourable zones or localities, and the animals of the Plankton which feed on them. The quantity of Phyto-Plankton present in a sea will then depend upon the balancing of the two antagonistic processes—the reproduction of the Diatoms and their destruction. We still require to know their rate of reproduction and the amount of the destruction. It has been calculated that one of these minute forms, less than the head of a pin, dividing into two at its normal rate of five times in the day would at the end of a month form a mass of living matter a million times as big as the sun. The destruction that keeps such a rate of reproduction in check must be equally astonishing. It is claimed that the 'Valdivia' results, and observations made since, show that the most abundant Plankton is where the surface water is mixed with deeper layers by rising currents.[2] Nathansohn, while finding that the hour of the day has no effect on his results, considers that the development of the Phyto-Plankton corresponds closely with evidence of vertical circulation. Like some other workers, he emphasises the necessity of continuous intensive work in one locality: such work might well be carried on both at some point on your great lakes and also on your Atlantic coast. The *Challenger* and other great exploring expeditions forty years ago opened up problems of oceanography, but such work from vessels passing rapidly from place to place could not solve our present problems—the future lies with the naturalists at biological stations working continuously in the same locality the year round.

The problems are most complex, and may vary in different localities—for example, there seem to be two kinds of Diatom maxima found by Nathansohn in the Mediterranean, one of *Chaetoceros* due to the afflux of water from the coast, and one of *Rhizosolenia calcar-avis,* due to a vertical circulation bringing up deeper layers of water. As a local example of the importance of the Diatoms in the Plankton to man, let me remind you that they form the main food of your very estimable American clam. The figures I now show, and some of the examples I am taking, are from the excellent work done on your own coasts in con-

[1] *Monaco Bulletin,* No. 140.

[2] A decade before, however, Whipple, and also C. Dwight Marsh, in America, had argued that the vernal and autumnal Diatom maxima in deep lakes were due to periodic 'overturning' of the water due to temperature changes and causing diatom spores and a large quantity of organic material to be brought up from lower layers to within the influence of sunlight.

nection with fisheries and Plankton by Professor Edward Prince and Professor Ramsay Wright and their fellow-workers at the Canadian biological station on your eastern sea-board.

The same principles and series of facts could be illustrated from the inland waters. Your great lakes periodically show Plankton maxima, which must be of vast importance in nourishing animals and eventually the fishes used by man. Your geologists have shown that Manitoba was in post-glacial times occupied by the vast lake Agassiz, with an estimated area of 110,000 square miles; and while the sediments of the extinct lake form your celebrated wheat-fields, supplying food to the nations, the shrunken remains of the water still yield, it is said, the greatest fresh-water fisheries in the world. See to it that nothing is done further to reduce this valuable source of food! Quoting from your neighbours to the South, we find that the Illinois fisheries yield at the rate of a pound a day throughout the year of cheap and desirable food to about 80,000 people—equivalent to one meal of fish a day for a quarter of a million people.

Your excellent 'whitefish' alone has yielded, I see, in recent years over 5,000,000 lb. in a year; and all scientific men who have considered fishery questions will note with approval that all your fishing operations are now carried on under regulations of the Dominion Government, and that fish hatcheries have been established on several of your great lakes, which will, along with the necessary restrictions, form, it may be hoped, an effective safeguard against depletion. Much still remains to be done, however, in the way of detailed investigation and scientific exploitation. The German Institutes for Pond-culture show what can be done by scientific methods to increase the supply of food-fishes from fresh waters. It has been shown in European seas that the mass of living food matters produced from the uncultivated water may equal that yielded by cultivated land. When aquiculture is as scientific as agriculture your regulated and cultivated waters, both inland and marine, may prove to be more productive even than the great wheat-lands of Manitoba.

Inland waters may be put to many uses: sometimes they are utilised as sewage outlets for great cities, sometimes they are converted into commercial highways, or they may become restricted because of the reclamation of fertile bottom lands. All these may be good and necessary developments, or any one of them may be obviously best under the circumstances; but, in promoting any such schemes, due regard should always be paid to the importance and promise of natural waters as a perpetual source of cheap and healthful food for the people of the country.

APPENDIX A.

PAPERS READ AT THE DISCUSSION ON 'WHEAT.'

Held at a Joint Meeting between Section B (Chemistry), Section K (Botany) and Sub-section K (Agriculture).

CONTENTS.

INTRODUCTION.

IN planning the programme for the meeting of the Association it was felt that no more appropriate subject could be chosen for consideration than that afforded by wheat, Winnipeg being now the focus point of a great area devoted to the growth of the cereal. Arrangements were therefore made in advance to hold a joint meeting of Sections B (Chemistry) and K (Botany) and of the Sub-section of Agriculture, for which communications were invited from various gentlemen known to be specially conversant with the subject in one or other of its aspects. The discussion took place on August 30, the President of Section B being in the chair. The papers then presented are here printed, together with an abstract of that part of the address delivered by the President of the Agricultural Sub-section which dealt with wheat; abstracts of two papers dealing with economic issues, communicated by Professor Mavor and Professor Brigham, are also appended to the discussion.

The civilised white man appears always to have enjoyed the use of wheat, no tradition being extant as to when it first became available. It holds a unique position among foods, being regarded as the staff of life; as other races of men have made acquaintance with it they have adopted it

in preference to other cereals; thus as a human food it is displacing rice, millet and other grains in the East, and maize on the American Continent. The production of wheat, in fact, is now one of the most fundamental of the problems of our time and also one of the most complex; it raises many issues, and many interests are concerned with it.

Many varieties of wheat are known, differing more or less in character and in requirements. The grower has to discover which variety or varieties are suited to the conditions of his locality and to cultivate that which will yield him most profit. It may well happen that the most profitable variety is not that which he can grow most easily, and he is in a measure obliged to effect a compromise.

In England, in the eastern States of America and other places where excess of water has to be avoided, drainage must be resorted to; elsewhere, in the western States of America and in India, for example, extensive irrigation works have been undertaken; where irrigation has not been possible special methods of cultivation are adopted, in order to secure the necessary supply of water—as among the natives of India and of Syria, and in the case of the system of so-called dry farming now in vogue on the western prairies of America. The old systems of husbandry were all arranged with the object of securing the maximum possible supply of food for the wheat plant.

Among the difficulties to be faced by the modern grower of wheat those due to drought, frost, and rust are the most serious.

Wheat is for a number of reasons an admirable crop for the pioneer. It is always saleable; it can be stored and sent long distances without deteriorating; of all agricultural commodities it is the easiest to transport. It is easily grown, requiring but little capital, and it does well on newly broken grounds; a few years of wheat cultivation affords an admirable opportunity of getting virgin land into condition for any other scheme of husbandry that may be desirable. As long as the present wave of expansion continues in Canada, Argentina, Australia, Russia, and elsewhere, enormous supplies of wheat will be produced under pioneer conditions, not necessarily as a permanent business but to some extent, at any rate, as a temporary expedient. During the last twenty or thirty years the supplies have been so cheap as to displace wheat from its premier position in the rotation system of long-settled countries and to convert it into a by-product. The change came quickly and caused terrible loss and suffering to farmers who failed to take notice of its occurrence and to alter their scheme of husbandry. But the change is not ended; the price of wheat is now going up—whether because of any slackening in the wave of expansion or, as some economists assert, because of the extraordinary output of gold in recent years, we need not discuss—and once more the proper place to be assigned to wheat in the scheme of husbandry becomes an open question.

The scientific problems are no less complex. Much must be done before the conditions necessary for the growth of wheat are fully elucidated. Although the requirements of the wheat crop are fairly well known, it is impossible at present to explain why a brick earth in Kent or Sussex will produce 45 to 55 bushels of grain without difficulty, whilst the stiff loam at Rothamsted only yields 35 to 45 bushels, no matter how well it be manured. The size of the crop is limited, among other factors, by the stiffness of the straw. If instead of standing up well the plants become 'laid,' it is costly to harvest; hence the farmer does not aim at the maximum crop but at the biggest crop that will stand. Stiffness of straw is influenced by a soil condition not yet clearly made out; crops will stand on one soil, while others of the same kind will be 'laid' on soil of a different type.

The different varieties of wheat are not all of the same market value.

The exacting requirements of modern civilisation necessitate special sorts of wheat for special purposes. The baker, the confectioner, the biscuit maker, all have their own requirements, and modern fastidiousness has put a price on subtle differences that were not recognised fifty years ago. Some very interesting problems have thus been opened up, but they are as yet far from being solved. In particular many investigations have been made to discover why certain flours—the so-called weak flours—only give small, squat, heavy-looking loaves, whilst others—the strong flours—will yield large, well-shaped, well-aerated loaves. The strong wheat commands the higher price, since the public insists on having the large loaf, but whether it is intrinsically more valuable, whether it is more nutritive, has yet to be ascertained.

But the grower is not directly interested in the intrinsic value of the various wheats: his object is simply to produce the wheat that gives him the highest profit per acre. It is clearly a first requisite that the wheat grown should be adapted to the local conditions and resistant to the local diseases. In England the 'weak' wheats are most profitable, in spite of their lower price per bushel; strong wheats do not yield sufficiently heavy crops to pay. One of the most important of the wheat problems of the day is to study the laws governing the production of wheat and see how far it is possible to impart any desirable quality by cross breeding. Is it, for instance, possible to breed a wheat that shall be as suited to the English climate as our present sorts are and at the same time possess the strength of the Manitoba wheats? Still more important for the future wheat-supply of the world are the questions whether it is possible to breed early ripening varieties and varieties resistant to rust—a pest which at present often seriously reduces the crop and is particularly troublesome in South Africa and India. If the process of maturation can be hastened only a few days, it becomes possible to extend the wheat belt further northwards and to escape the harvest frosts which sometimes cause so much trouble in Canada. Drought-resisting wheats are also wanted—varieties with narrow leaves and therefore less likely to lose water by transpiration.

The improvement of wheat by selection, in other words the search for new mutation forms, is going on in all parts of the world but was necessarily uncertain so long as progress depended on accident. The republication of Mendel's work, however, has given an impetus to the study of cross-breeding and it is now possible to predict the way in which certain characters of the parents will appear in the offspring. It is not too much to say that when the virgin regions of the world are all inhabited the total production of wheat will be limited only by the limit set to the plant-breeder's work.

Speculation as to the future world-supplies of wheat are always interesting but are particularly liable to be falsified. The factors are incompletely known. We are only now beginning to make soil surveys. Yet without some sort of a world survey it is impossible to say what area is suitable for wheat culture. It is not known how far improvement of the cropping power of the plant is possible and whether we can ever hope to exceed the present run of yields under our present conditions of soil and climate. Nor is it known whether varieties can be found or made to grow in regions at present unsuitable, as, for instance, in northern latitudes where the summers are short though the days are long, or in the vast areas of the world where the rainfall is too small. It is especially difficult to attempt forecasts at the present time, when the dominating factor in the world's supply is the essentially transient supply sent in by pioneer workers in new countries. However, all countries are alive to the importance of the problem and work on the subject is beginning in most of them.

1. *On the General Economic Position of Wheat Growing and the Special Considerations Affecting the North-West of Canada. A Résumé by* Major P. G. Craigie, *C.B.*

In the address which opened the deliberations of the Sub-Section of Agriculture (printed in full in the Transactions of the Association), the Chairman invited attention to the paramount influence exerted on problems of this type by the varying growth of population and the relative degrees in which from time to time different regions of the earth contributed to the production of wheat.

A review of the available statistics made it plain that, although some effort had been made to feed the largely augmenting populations of Western Europe by securing an increased yield from the acreage previously employed, it was mainly from the surplus of certain still exporting States of Eastern Europe, and from the ample and more lately peopled areas of North and South America, and in a minor degree Australia, that the inevitable deficit of bread corn in this quarter of the earth's surface had to be supplied. Although it was opportune and appropriate to enter at this Winnipeg meeting on a careful examination of the local features attending the rapid acceleration of wheat-growing in the North-West, sound conclusions respecting the relative extent of the future supply to be drawn from any single geographical area involved an examination of world-wide problems.

The conclusions of the statistician and economist were required, as well as the advice of the scientific investigator and experimentalist, before an answer could be given to the question whether, how far, and at what rate, with profit to himself and with benefit to the bread consumer across the ocean, the Canadian agriculturist—in the face of the conditions now existing or likely to prevail—could push the further extension of the well-nigh eight million acres of wheat land which the Dominion claimed to show in 1909.

By way of clearing the ground for this local discussion, reference was made to the effect of more recent statistics in dissipating the alarm which had been raised in 1898 by Sir William Crookes—largely on the authority of earlier data supplied by an American statistician—that the wheat-producing soil of the world, as a whole, was becoming unequal to the strain put upon it by the multiplication of bread-eaters; and that a wheat famine could only be averted by materially raising the world's average of wheat yield per acre on the surface at present devoted to that cereal by the beneficial magic of the chemist in making available a fertilising supply of nitrogen sufficient to raise that average nearly 50 per cent.

As a fact, much greater progress had been made in extending the wheat-fields of the globe in various directions from 1897 onwards than in the years between that date and 1884. Even supposing it were true that the growth of men had outstripped the growth of wheat areas between 1884 and 1897 the recorded extension of the world's wheat-fields in the next decade was well over that of population.

The remarkable period of stagnation, which left the areas under wheat in the United States in 1893-97 no higher than the 35,500,000 acres at which they stood in 1878-82—a phenomenon which so largely affected the pessimistic conclusions of 1898—had given way to renewed advance even in that region, and to more remarkable developments elsewhere. An upward bound of the curve of progress could be traced, not only in new but in some old-world exporting countries. Far too little attention had been given to the statistics which showed how, even in European Russia—as well as in Caucasian and Asiatic provinces of that Empire—wheat growing had increased, while the new factors of Argentina and Canada were playing a part far more potent and significant as to their future possibilities than was credited to them ten years ago.

Supplementing the details of the existing wheat areas of the world by estimates from other countries, and employing in certain cases later statistics now available, it seems probable that approximately 242,000,000 acres are at the present time devoted to the growth of this cereal, three great States or combinations of States supplying 150,000,000 acres of this total. Roughly, the distribution of the surface may be analysed as under, indicating the development of the last decade:—

Regions	About 1898-99	About 1908-09
	Acres	Acres
British Empire	35,000,000	42,000,000
Russian Empire	47,000,000	60,000,000
United States	40,000,000	48,000,000
European States (not included above) .	60,000,000	64,000,000
South America	7,000,000	16,000,000
Minor States (partly estimated) . .	12,000,000	12,000,000
	201,000,000	242,000,000

So far as the defective records of still earlier periods than the above may be quoted, the total acreage of the wheat-fields of the world in 1883 may have been slightly over 170,000,000 acres, and in 1893 about 190,000,000 acres. Since it may be assumed that no appreciable increase is shown in the 26,000,000 acres of wheat in India, included above in the total for the British Empire, and no increase in the estimates of the last line of this table is presumed to have taken place, the localities where the greatest development of wheat-growing has occurred may be readily traced, and the accelerated rate of the extension in the most recent decade offers an assurance that the apprehended shortage of bread-supplies is not yet in sight.

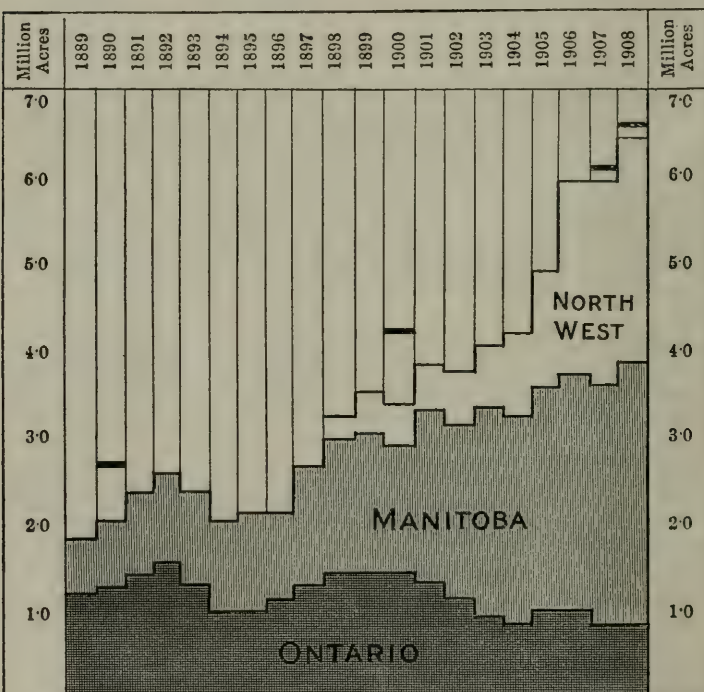
Estimates of the world's aggregate production are even less complete and reliable than those of acreage, but, comparing the figures forthcoming for the average of the three years 1895-97 with those for the last three harvests 1907-09, a total of 2,444,000,000 bushels of wheat would appear to have risen to 3,236,000,000 bushels, an advance of nearly 33 per cent. in this interval. This movement is certainly much greater than that of population in the period covered.

In view of the concern of the United Kingdom in the expanding imports of wheat, the following statement emphasises the changes which have occurred in the chief sources whence its supplies have been received, and illustrates the growing importance of the Canadian contribution to the needs of the Mother Country.

Annual Average Imports of Wheat and Wheat Flour (expressed as Grain) into the United Kingdom and the Countries from which these Imports were recorded in the Trade Accounts in millions of cwts.

Periods	Total received	Of which from						
		U.S.A.	Argentina	Russia	India	Australasia	Canada	All other
1881–85 (5 years) .	77·3	41·4	0·1	9·0	9·4	4·0	2·7	10·7
1886–90 ,, .	77·8	37·4	1·2	14·5	9·2	1·9	3·4	10·2
1891–95 ,, .	96·6	50·7	7·7	13·8	9·2	2·9	4·9	7·4
1896–1900 ,, .	96·0	57·3	8·1	9·2	4·1	1·6	7·5	8·2
1901–05 ,, .	111·6	42·3	14·6	15·0	15·5	7·1	10·5	6·6
1906–08 (3 years) .	112·5	36·8	24·4	10·2	11·3	7·7	15·2	6·9

After illustrating the records of this renewed advance, the distinctively Canadian features of the movement were discussed in the address, and the difficulties which an investigator encountered in forecasting the future was acknowledged. Some illustrations of the widely divergent conclusions of competent experts were found in the discrepant estimates which Professor Mavor had collected (without himself adopting) from acknowledged authorities in his exhaustive Report of 1904. One of these estimates, it will be remembered, placed the land fit for settlement or 'susceptible of cultivation,' in the North-West as low as 92,000,000 acres, and another as high as 171,000,000 acres. One skilled estimator restricted the surface likely to be annually available for wheat to an aggregate of 13,750,000 acres, while another offered more than three times that figure, or 42,750,000 acres. The resultant produce anticipated in the one case represented 254,000,000 bushels and in the other 812,000,000 bushels, while the higher figure had the high authority of Dr. Saunders. It was, therefore, for the experts now assembled to say



NOTE.—(*a*) The single black line across the columns for 1890, 1900, 1907, 1908, represents the estimated total acreage of the Dominion of Canada for which no continuous series of statistics exist.

(*b*) Were the preliminary estimates for 1909 taken into account, the total acreage would have been given as 7,750,000 acres—a rise of 1,139,000 acres in the latest twelve months. This is indeed the net result, for the West has added 1,402,000 acres—of which 1,289,000 were in Saskatchewan and 113,000 in Alberta —while there are declines in the East and in Ontario of 114,000 acres, and likewise a reduction of as much as 149,000 acres in Manitoba since 1908.

if the lapse of another quinquennium full of interesting movements, both of population and of crops in the North-West, had enabled them to arrive at any greater certainty as to the future.

It was incumbent on those who forecasted the wheat areas of coming years carefully to avoid exaggeration and loose deductions, and whatever ample surfaces they believed to await the wheat grower, and whatever tales were told of practically inexhaustible regions yet untapped, they must not neglect to bear in mind the necessity of enlisting for the improvement of the yield the very promising aid which science in many directions, whether botanical or chemical, was now beginning to offer to the farmer.

The vast territories still available in the North-West should not in any case be looked upon as a mere wheat mine to be exploited and exhausted by the recurrent culture of a single cereal. The successful farming of the future, here as well as elsewhere, would demand more careful tillage, more scientific rotations, and a watchful consideration of the changes going on in other lands in the grouping of the populations and the opening of other wheat fields than their own.

As a guide to the ascertained movements of the Canadian wheat area which the local statistics so far available afforded, the subjoined illustration was offered representing the areas as recorded separately in Ontario, in Manitoba, and in the North-West respectively since 1889. This showed how the area had diminished in the older province, where farming was becoming more mixed, and how it had extended in Manitoba, and still more rapidly in Saskatchewan and Alberta.

Professor Mavor's Paper.

In a paper bringing up to date the conclusions of his Report to the British Board of Trade in 1904, discussing the production of wheat in the North-West of Canada (printed in full in the Reports of the Association, p. 209), Professor Mavor explains the changes in the administrative divisions known at the earlier date as Alberta, Assiniboia, and Saskatchewan, and the extension due to their absorption of almost the whole of the former territory of Athabasca. The surface now included in the three provinces of Manitoba, Saskatchewan, and Alberta covers 357,000,000 acres of land and nearly 13,000,000 acres of water—together, 370,000,000 acres—as against 238,000,000 acres in 1904, the additional 50 per cent. lying, however, beyond the region of practical settlement for commercial production at the present time. The experience of the later five years strongly confirms Professor Mavor in his conclusions of 1904 that very great improvements in the productive powers of the country, and a very considerable increase in the effective population, as well as a more exclusive regard to wheat cultivation would have to take place before the North-West could be relied upon to produce for export to Great Britain a quantity of wheat even nearly sufficient for the growing requirements of that country. This exclusive attention to wheat he regards as unlikely to arise, since, even were the soil uniformly suitable and the seasons absolutely reliable, the disposition of the people, and their settlement in small farms, of which the owner is also the cultivator, seems against such exclusive cultivation of one crop. The advice of the experimental farms, the Governmental encouragement of mixed farming, and the experience of the States immediately south of the international boundary, are all counter to continuous single-crop culture.

The writer makes the net gain in the North-West Provinces by immigration and by natural increase of immigrants between 1901-06 a total of 369,000, and adds that there being no reliable available statistics of either births or deaths in the North-West, the actual natural increase cannot be stated. In 1907-08 immigration had largely increased—the number received that year being the largest in the history of the country.

The policy of the distribution of immigrants in small isolated groups is then discussed, and a careful analysis given of the available statistics of immigration and the progress of cultivation and the relation traced between the increase of cultivation and the growth of the population. Professor Mavor puts the cultivated area per head of population as 8·6 acres in 1901, of which 5·9 acres was in wheat, whereas in 1906 the cultivated area was 9·9 acres, of which 6·3 was in wheat—*i.e.*, 62 per cent., as against 68 per cent. at the earlier date. He traces the diminished proportion of wheat growing to the total acreage under all grain crops, which he puts as declining from 62·56 per cent. in 1905 to 55·44 in 1909, the drop being greatest in the latest years, 1908 and 1909. Oats, on the other hand, had shown the greatest proportional increase, from 24·86 per cent. to 33·57 per cent. This, however, he attributes chiefly to the amount of railway construction and employment of horses that has been going on in the three provinces.

The unsatisfactory condition of the collection of agricultural statistics in Canada at present, and the inconvenience of the periodic presentation of two differing sets of statistics—one compiled by the Dominion Government and another by the provincial authorities—is illustrated by Professor Mavor in the discrepancy of 16 per cent. between the wheat crop of 91,853,000 bushels given in 1908 by the former and that of 107,002,093 bushels by the latter for the three prairie provinces, while the latter figures seem to be adopted by the Dominion Department of Trade and Commerce. He advocates the employment of more expert statistical officers and an adequate agricultural survey of the whole region. Without this only 'fanciful' conclusions could be reached about the future productivity of a vast and very varied country.

Professor Mavor points out that the yield of wheat per acre since 1898 exhibited a fluctuation of from 9·11 in 1900 to 25·16 in 1901, being twice above 20 bushels and four times below 16. He finds no justification for multiplying the estimated acreages by the arbitrary figures of 20 bushels.

Irrigation notwithstanding, he finds no evidence that the semi-arid area can be relied upon to produce any considerable amount of wheat for export, but notes a very rapid increase in miscellaneous farming in this area; and he traces the progress of three irrigation schemes in the semi-arid regions of Alberta, giving interesting particulars of the largest scheme, that of the Canadian-Pacific Railway, which contemplates dealing with 3,500,000 acres of land and involves at present 1,000,000 acres.

The Paper further offers in detail interesting particulars of the course of land values, and a table is given of the advancing values per acre in the sales of land belonging to the Canadian-Pacific Railway from $3·15 in 1901 to $9·54 in 1908.

After discussing the various railway extensions and their bearing on the development of the North-West, Professor Mavor concludes his Paper with a reference to the varying estimates of possible wheat production quoted by him in his Report of 1904 from different expert authorities, and offers an amendment by those responsible for the lower one of 13,750,000 acres, which would, in the light of recent progress, add another 3,500,000 acres to that total, and a consequent enlargement of the resultant produce of this lowest estimate to 317,000,000 bushels, which would provide 232,000,000 bushels for export. He repeats, however, his own distinct disclaimer of any responsibility for the original estimate or its amendment, and urges, as before, the very numerous economic factors which have to be borne in mind in estimating the productivity of any country in this respect. He concludes that no one who examines the statistics of agricultural productivity in the North-West since 1883 can fail to be astonished at the progress made in twenty-six years. In 1883 the population was insignificant, and the one railway then constructed had not been completed to the coast. Now three great railways are crossing these provinces, and another

forcing its way upward from the States. The population numbers a million, and its agricultural prosperity is advancing by leaps and bounds. The country, he adds, needs no fantastic exaggerations to draw attention to its achievements and its possibilities; it only needs a cool estimate of these and consolidation rather than excessive expansion. A vast amount of energy and capital has been wasted in attempts to exploit regions which are, and must long remain, distant from markets, while fertile soils easy of access have remained under cultivation of a highly primitive character. The immense natural resources of the rich soil of Manitoba and of portions of Saskatchewan and Alberta are not even yet being fully exploited. Very considerable improvements in agricultural methods must yet take place if their resources are to be fully utilised.

Professor Brigham's Paper.

A paper by Professor Albert Percy Brigham dealt with the development of wheat culture in North America generally. As may be seen from the text of this paper printed in the Reports of the Association (p. 230), its scope covered the history of the cultivation of this cereal and the striking changes which had occurred in the distribution of the area so occupied within the United States, the movement of wheat exports, and the prospects, on the one hand, of an increasing consumptive demand, and, on the other, of an augmented yield per acre from more scientific modes of farming. Professor Brigham quotes a variety of opinions as to the future of wheat growing within the United States, and the various factors which have to be weighed before the declining importance of the American export trade become evident. He accepted the view that the future development of cereal cultivation in his own country depended more on improved methods than on adding new lands. If the United States has 150,000,000 inhabitants at no distant date, they would need 900,000,000 bushels of wheat for home supply. As already 700,000,000 bushels had been reaped in one year, an addition of only four bushels per acre on existing areas would fill the gap, while if they could add another 10 or 12 million acres they could keep up the present scale of export.

Towards the close of his paper Professor Brigham approached the remarkable conditions attending the wheat areas of the North-West of Canada and its capacity for future development.

He pointed out that, in comparison with some of its competitors, Canada was old in this industry, raising 20,000,000 bushels in 1827, while Argentina only began in 1882. The high level of the present Canadian yield was noted owing to the natural fertility of the prairies, the greatest crop ever raised from unfertilised land being credited to Canada in 1901, when 63,425,000 bushels were raised on something more than 2,500,000 acres, or more than 25 bushels per acre. Professor Brigham quoted on the authority of Mr. Blue, of the Census and Statute Office at Ottawa, the crops recorded in each year of the present century (1900-08) separately for each of the three provinces of Manitoba, Saskatchewan, and Alberta. The exports of Canadian wheat ranged from sixteen and nine millions respectively in 1900 and 1901 to a maximum of 43,654,668 bushels in 1908. With reference to the recent northerly attempts at wheat growing, he quoted the experiments in the Peace River district at Fort Vermilion, 350 miles north of Edmonton, where 35,000 bushels had, according to Dr. Wm. Saunders, been raised in 1908.

If there was to be prophecy as to Canada's future product, her own experts must play the part of seer. He had not seen any retraction or modification made by Dr. Saunders of his 'reasonable prophecy' of 1904 that wheat grown on one-fourth of the land suited to it in the Canadian

North-West with the yield of Manitoba in the previous decade would bring a crop of more than 800,000,000 bushels. If there be such a surplus of good soil as three-fourths, ample room would be left for diversified crops and such rotations and following as might be needful in future years to meet the declining production of the prairie soils.

After a reference to Sir William Crookes' forecasts in 1898, and the extent to which later data had outstripped his modest expectations, Professor Brigham declared it 'hazardous' to set limits to wheat in view of possible unknown factors of production.

Sufficient account had not been taken of the limitation of population among the nations of the higher standards, who are bread-eating peoples. Any presure on the wheat supply would foreshadow itself before the pinch came, and would tend to still further restriction of population. He agreed with an earlier conclusion of an American economist (Mr. D. A. Wells) that the world 'for the first time in its history has now good and sufficient reasons for feeling free from all apprehensions of a scarcity or dearness of bread.' Any increased demand in Western Europe, or more truly by North-Western Europe, would be fully met by developments in Canada, Russia, Argentina, Egypt, India, South Africa, and Australia, so that they might even leave out the United States, or even omit India should her wheat be needed at home to avoid periods of famine. Argentina was as yet undeveloped, and Russia backward in bringing her vast resources to full effect on the world's market. North America had the land, progressive appliances, skilled energy, and facilities of transport to supply the bread market of coming decades. No citizen of the United States of America need harbour a jealous thought if in that market a major place should come to her northern neighbour.

---

2. *The Factors determining the Yield of Wheat.* *By* A. D. Hall, *M.A., F.R.S., and* E. J. Russell, *D.Sc.*

The Rothamsted experiments on wheat began in 1843 on the Broadbalk field on which wheat has been grown every year since. In the first few years a general idea was obtained of the requirements of the plant as regards manure; a scheme for the treatment of the plots was drawn up in 1851, and has been substantially adhered to ever since.

(1) Food.—The chief elements of nutrition derived from the soil or manure are nitrogen, phosphoric acid, and potash; lime, magnesia, soda, sulphuric acid, and silica also play their part, but are supplied in sufficient quantity by all ordinary soils.

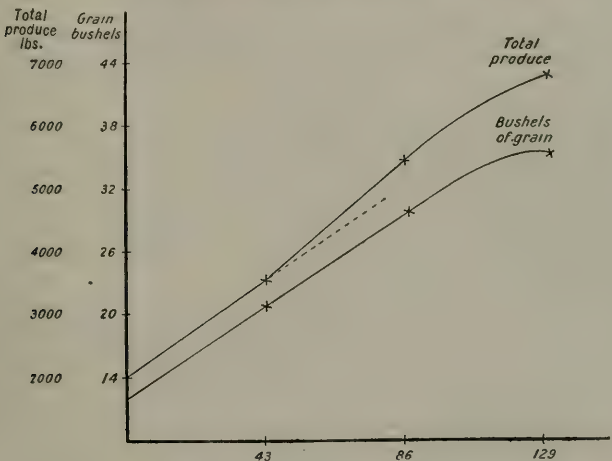
Nitrogen.—At the time the experiments were commenced the necessity for nitrogenous manures was denied by Liebig; several of the plots were therefore arranged to show the effects of different amounts and various forms of nitrogenous manure. It was soon demonstrated that nitrogenous manures were necessary and that the yield was proportional to the nitrogen supplied. The action of two sets of factors may be traced in the results.

(*a*) If we have a series of plots, each receiving more phosphoric acid and potash than the plant can possibly require, the yield on each plot should be strictly proportional to the supply of nitrogen if the wheat plant be able to deal with all the nitrogen it receives. The amount of food a plant takes up, however, depends on the extent of the absorbing root surface. At first an increase in the amount of nitrogen in the soil increases the root system, and therefore the absorbing surface, as well as the amount of material that each unit of this surface can take up. Hence the yield is more than proportional to the supply, *i.e.*, the second increment of nitrogen on Plot 7 produces a larger increase than the first increment on Plot 6. When yield is plotted

against supply of nitrogen the curve begins by being concave instead of linear. (Curve 1.)

There are a few exceptional years in which this relationship does not hold.

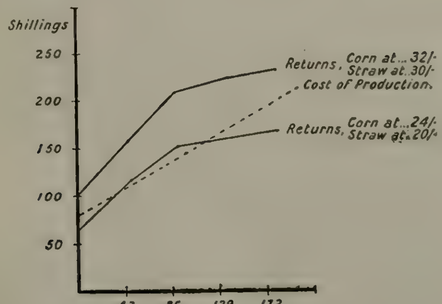
(b) When further amounts of nitrogen are supplied other limiting factors come into play, the increase being smaller for the third and fourth



Nitrogen supplied, lbs. per acre.

CURVE 1.—Effect of increasing supply of Nitrogen on the yield of Wheat.

increments of nitrogen. The curve of production becomes convex, illustrating the law of diminishing returns. There is an important practical application of this curve in districts where it is customary to manure for wheat. So long as the increased crop is more than proportional or is simply proportional to the supply of food, it may be profitable to go on adding manure. But when the yield falls off, a point is reached where further additions of manure are unprofitable.



Lbs. Nitrogen supplied per acre.

CURVE 2.—Returns from plots receiving varying quantities of Nitrogen.

The diagram No. 2 shows the results obtained during a selected period of thirteen years, when there were four plots receiving regular increments of nitrogen. The vertical distance between the dotted line (cost of production) and the curve of returns shows the profit or loss accruing from the varying quantities of manure. Up to a certain point, the better the farming the higher the profit; beyond this the profit falls off. The curve illustrates the law of diminishing returns and also Lawes' dictum that 'high farming is no remedy for low prices.'

The general principles which have just been illustrated that the earlier increments of nitrogen may produce increased yields more than proportionate to themselves, while later amounts are followed by a constantly diminishing increase—*i.e.*, that the curve of production is first concave and then convex—is true not only of nitrogen but of manure generally and of any of its simple constituents, should the experiments begin with a deficiency and end with an excess. The principle is also applicable to water supply and to many other factors, each of which may limit the crop production. For example, in arid climates the yield is generally unaffected by the supply of nitrogen because it is determined wholly by the water supply, enough nitrogen being always present to satisfy the needs of a larger crop than the limited water supply will permit of.

Phosphoric Acid.—Unlike barley and turnips, wheat does not respond to large quantities of phosphoric acid, but is well able to satisfy its requirements from the soil. Phosphoric acid, of course, is necessary, but its most marked effects are secondary. It hastens maturity, and is therefore effective in a backward season or in late districts, since it enables a crop to be harvested in time which otherwise might be damaged or lost. Extraordinary returns are obtained for small quantities of superphosphate in Australia.

Potash.—Wheat is usually able to satisfy its potash requirements from the soil, but at Rothamsted, on the plots which have become depleted of potash, the deficiency is shown by a reduced yield, especially in dry seasons, and by increased tendency to disease, rust, &c.

Organic Matter.—Autumn-sown wheat is less dependent than most farm crops on good texture of the soil, and grows freely even when the amount of humus in the soil is a low one. On the Rothamsted plots, where wheat has been grown for so long with manures containing no organic matter, no difficulty is experienced in obtaining a plant; the seed germinates and grows away freely. Similarly Prout at Sawbridgeworth has grown wheat and other cereals on the same land since 1864, using no farmyard manure, and growing clover (the roots and stubble of which would supply some humus) only about once every seven years. In England it is not customary to use much manure for wheat; in the Eastern Counties farmyard manure is very generally put on the temporary hay or clover before it is ploughed for wheat, but this is to some extent a matter of convenience in handling the manure. Beyond this, specific manures are rarely employed, except perhaps soot or a top dressing of nitrate of soda in the spring if the plant is backward. Wheat is usually grown after clover or a well-manured mangold crop, and therefore on land recently enriched with nitrogen; an excess of phosphoric acid is also generally applied to the turnip crop in the rotation, and its influence persists until the wheat crop comes round.

(2) Rainfall.—Wheat being a deep-rooting plant and sown in England in autumn, is less dependent on spring and summer rainfall than most other crops. Thus the very dry years—1854, 1864, 1898—were all good wheat years; indeed, an old English proverb runs: 'Drought never bred dearth in England.' The lowest rainfall was in 1864 (18.5 inches) and the crop was above the average, especially on the plot receiving dung. Further, the great wheat-growing districts of England are also those of lowest rainfall. Wheat is, therefore, one of the crops best adapted to dry regions, probably

not because it requires relatively little water, but because it flourishes best in a dry atmosphere, and possesses a large root system well able to supply the plant with water from that stored in the subsoil. It is generally recognised that wheat grows best in comparatively heavy soils, which retain a considerable store of the winter's rains for the service of the crop in the summer.

The effect of high rainfall is harmful in several directions. If it comes in autumn it washes nitrates out of the ground and militates against the development of a full root system, the chief process going on in late autumn and early winter. There is, therefore, a reduction of crop; indeed, over a period of years almost a mathematical reduction. Shaw has shown that the average crop in England varies above and below a certain limit in inverse proportion to the rainfall of September, October, and November, his formula for the Eastern Counties of England being—yield = 46 bushels—2·2 rainfall in inches. This formula only holds if the weather conditions later in the growth of the plant are normal; *i.e.*, a high yield is only possible if the autumnal rainfall has been low, but a low autumnal rainfall may on occasion be followed by a low yield because some factor depressing the yield has intervened later. If much rain falls at or a little before harvest time the corn does not ripen well, and is in any case difficult to get in. It is this circumstance that limits the northward extension of wheat in the British Isles. The limit can be pushed somewhat further by the use of phosphatic manures, which tend to hasten maturity and thus enable the harvest to be got in a few days earlier.

On the other hand, a good rainfall towards the end of spring is beneficial, especially if the spring is early; such a rainfall is a usual feature of the good wheat seasons. It is significant also that the exceptional years already referred to, in which the second increment of nitrogen produces *less* effect than the first, are generally years of low spring rainfall.

(3) TEMPERATURE.—High temperatures are not at all necessary for the production of wheat, excepting at the time of maturation. In the best seasons it commonly happens that the summer (June and July) temperature is *below* rather than *above* the average. For winter-sown wheat, a mild open winter, not too wet, is desirable to bring the plant forward in early spring but is by no means essential.

Spring Wheat.—The conditions regulating the growth of spring wheat are not quite the same; owing to the shortened period of growth the yields are rarely so high, and the crop appears to be more susceptible to rust and other diseases. For a good yield it is essential that the soil shall contain enough moisture to ensure a good start to the seed, but any excess of rainfall in the first month or two of growth is prejudicial because it restricts the development of the root system. Little is known directly of the manurial requirements of spring wheat, but probably, like barley and oats, it is less dependent upon nitrogen but more on phosphoric acid than autumn wheat.

The wheat plant in climates like that of England continues to take some food from the soil—nitrogen and phosphoric acid, for example—almost up to the time of harvest. Assimilation also continues as long as any part of the stem or leaves is green.

The process of seed formation consists in transferring previously stored starch, protein, &c., from stem and leaf to the seed, but the material transferred has much the same composition in the earlier and later stages of the process. That wheat which has been prematurely ripened through excessive drought or an attack of rust is exceptionally rich in nitrogen is probably due to the loss of carbohydrate from the grain by continued respiration, and not to gluten entering the grain first, to be followed by carbohydrates only in the later stages of filling.

The ripening process appears to be mainly one of desiccation.

(4) Continuous Wheat Growing.—At Rothamsted, where wheat has been growing on the same land for more than sixty years, there is little evidence of any secular decline in the yield due to the constant repetition of the crop, provided that sufficient fertilisers are supplied. On the unmanured plot and in cases in which complete fertilisers are given, the production tends to reach a constant level when long-period averages are taken to exclude the fluctuations due to season. That the Rothamsted yields are never so high as are sometimes attained under ordinary farming conditions is due to the type of soil and certain difficulties in cleaning and preparing the land when wheat follows wheat so rapidly.

(5) It is not, however, possible to analyse completely all the factors involved. Type of soil in relation to climate is very important. Thus the Rothamsted plots, even those receiving abnormally large dressings of manure, have only on two occasions (1864 and 1894) approached 50 bushels, which on a good brick earth would be by no means an exceptional crop even when grown, as usual in England, with but little manure. To each type of soil there is a limiting yield beyond which the crop will not go. But the limit is not the same for all varieties; it is not unusual to find that one variety may do much better than another under one set of conditions but not so well under others. There is still a good deal of work to be done in inquiring into the soil conditions and reducing to precise terms such vague expressions as ' a good wheat soil.' For example, on soils not very dissimilar, with the same rainfall and management, a heavy wheat crop will stand in one case, while on the other soil it will invariably go down, and as yet it is impossible to state definitely the factors which thus determine the stiffness of straw in one case and not in another. As wheat is largely a pioneer crop, and as the pioneer cannot control his conditions to anything like the extent that is possible in more developed parts of the country, it is important that wheat should be bred to suit local conditions.

---

3. *The Breeding of Wheat. By* Professor R. H. Biffen, *M.A.*

The widespread cultivation of wheat from very early times has led directly to the production of a very large number of distinct varieties, so that growers have abundant opportunity of choosing those which best suit their special conditions of cultivation. Wide as the choice is, however, few will care to admit that they have precisely the varieties they could wish for at their disposal; the improvement of existent types is, in fact, demanded in practically all directions. In most parts of the world the features of outstanding importance are strength, resistance against disease, and yield. Under certain conditions the power of resisting drought and that of maturing early are also of extreme importance, and any improvements in these directions would lead at once to a great increase in the area within which the crop can be cultivated.

Most of the wheat-growing countries recognise these facts, and several have made considerable efforts either to find wheats suitable for their needs or in some cases to produce them by cross-breeding. In Australia, Canada and the United States such wheat-breeding experiments have been in progress during the past twenty years. On the whole the experiments cannot yet be said to have met with the success they deserve, with the possible exception of Farrer's in Western Australia, which promise to effect radical alterations in the types of wheat cultivated there. The reasons for this partial failure are now obvious. Breeders had no definite knowledge of the results to be expected from any particular cross. They knew in a general fashion that the operation resulted in 'breaking the type' or inducing 'great variability,' and there was always a hope that amongst the

variants some form would be found superior to its parents. Looking back on the records it is now obvious that the majority of their crosses were very unlikely to give results of value. Even when the desired types were found, the difficulties were by no means overcome, as it was necessary to fix the new variety; under the old conditions, this generally meant years of tedious 'selection' and often ultimate failure.

The republication of Mendel's work and its speedy confirmation and extension altered the whole aspect of affairs by giving a rational explanation of the phenomena which had so puzzled breeders. It was proved that the variants were the results of recombinations of characters, obvious or otherwise, already existent in the parents; furthermore, it showed how the essential fixity of type could be secured.

To put wheat breeding on a certain basis it was necessary in the first place to trace the mode of inheritance of the many characteristics which in various combinations make up the existent varieties of wheat. With some few exceptions this has now been done, and it has been shown that nearly all the outstanding features of importance from an economic point of view 'Mendelise' and can be brought together in any desired combination. Thus, by way of an example, a wheat of the general character of Rivett wheat, with its beard, grey colour, and rough chaff, but producing strong grain like that of Red Fife, can be bred and fixed in three generations by crossing Rivett wheat and Red Fife. Again, the same cross will give the corresponding beardless or white and smooth-chaffed types.

In view of the steadily increasing demand for strong wheats and the general shortage of the world's supply of such sorts much attention has been paid to the inheritance of this characteristic. To simplify matters a strong wheat was defined as one capable of yielding a light and well-piled loaf—that is to say, a loaf of large volume, which stands well and does not flatten out in the baker's oven. Such a definition was necessary in view of the conflicting opinions current as to the real meaning to be attached to the term 'strength.'

Before deciding on the best varieties to use as strong parents many preliminary trials had to be made. These tended to show that strength was not so simple a characteristic as might have been expected. Many varieties possessing this feature in a high degree in their own countries, when grown under our climatic conditions gave wheat no stronger than our own weak sorts. This appeared to be particularly the case with some of the finest of the Hungarian varieties. Some few varieties, on the other hand, produced excellent grain when grown year after year in this country. One of the best examples of these varieties is Red Fife, or Galician wheat. This has now been grown over a period of sixteen years, chiefly in the West Midlands but also in many other parts of the country, and its grain can still compete on equal terms with the Red Fife imported from Canada as 'Manitoba Hard.'

It is with strength of this type—the strength determined not merely by climatic conditions, though possibly varying a little from season to season —that the breeders of this country are concerned. Further, as Red Fife appears to retain its strength wherever it is grown, it is not improbable that this variety will prove to be the progenitor of the world's strong wheats in the future. Unfortunately there are many drawbacks to its cultivation in this country, and it is doubtful whether it will ever become one of our staple varieties, except, possibly, in some few localities. On many soils it is an indifferent cropper, and even in those places in which it gives a satisfactory yield the straw does not stand as well as that of our common wheats. Could the breeder only combine its excellent quality of grain with a heavy cropping capacity and stiff straw he would obtain a variety which would go far towards making wheat again the most profitable crop of the farm.

The solution of such a problem requires a knowledge of the inheritance of characteristics peculiarly difficult to deal with. A casual inspection of a plant is sufficient to determine whether it is bearded, velvet-chaffed, red, &c., but strength, yield, and stiffness of straw cannot be determined so steadily. In fact, the single plants the breeder now deals with—instead of the mass, as before—give him no information of value as to capacity to afford a heavy yield of grain or stiff straw. Such features can only be determined by actual and, in view of their number, costly field trials. In the characteristic 'strength' the problem is not quite so complex, as by choosing varieties showing extremes of strength and weakness as parents it is possible to differentiate these with sufficient accuracy for technical purposes when segregation has occurred.

The mode of inheritance of strength was first determined by crossing Red Fife with Rough Chaff, the former parent having strong grain of a red colour, the latter weak grain of a white colour. Like most weak wheats, the grain of Rough Chaff is soft and of a texture well described as floury, whilst that of Fife is hard and translucent. The texture of the grain has proved singularly constant under our experimental conditions and a good index as to the baking quality of flour from the grain. The generation raised from the plant arising from this combination of the parents, the $F._2$ of the Mendelians, showed obvious segregation into strong and weak wheats, these characteristics being entirely independent of such others as the velvet nature of the chaff, the grain colour, &c. Thus in this generation the following obvious types occurred:—

Strong, velvet-chaffed, red.	Weak, velvet-chaffed, red.
Strong, velvet-chaffed, white.	Weak, velvet-chaffed, white.
Strong, smooth-chaffed, red.	Weak, smooth-chaffed, red.
Strong, smooth-chaffed, white.	Weak, smooth-chaffed, white.

On determining the proportion of strong-grained to weak-grained individuals there were found to be three of the former present to every one of the latter, the distribution of the two forms being uniform in the eight types mentioned above. Strength in this case, then, proved to be simply dominant to lack of strength. In the following season a number of pure strong types were isolated and grown on again the following year, in order to obtain sufficient grain for tests in the bakehouse. The results of these tests confirmed the view arrived at from an examination of the grain of the $F._2$ generation, and left no doubt that the strength of these hybrids was of the same order as that of the parent Red Fife.

In many other cases the simple Mendelian ratios are not so readily ascertainable, owing to the varieties chosen as the weak parents producing semi-translucent grain. Under such conditions the well-known chewing test of the wheat buyer is generally sufficient to show that segregation has occurred and to enable the breeder to pick out the strong types for further tests.

Whilst these investigations were in progress some of the late W. Farrer's Fife crosses were being obtained in sufficient bulk for baking tests. These also proved to be 'fully as strong as Fife.' Thus the facts at our disposal seem to warrant the statement that strength is a unit character. Complications may and probably do exist, much as they do with the colour characteristics of wheat, but of this nothing is known at present; so far the only exception taken to this view has been based on cases in which the actual baking strength of the parent plants is unknown.

The strong wheats of the world are at present cultivated almost exclusively in countries in which the yield per acre is small; where large yields are the rule the weaker types only are in general cultivation. It has consequently been assumed that strength and lowness of yield are correlated

with one another. If this view be correct, the combination of heavy yield with strength is an impossible one. At present little evidence can be brought forward from one side or the other, though it is worth noting that in some few districts in England Red Fife crops as well as Square Head's Master. Such fresh evidence as can be brought forward at this stage points, however, to the incorrectness of the general view, and seems to show that a heavy crop of good quality is by no means an impossibility.

The best proofs of its possibility or otherwise would be afforded by a detailed study of the inheritance of yielding capacity, a matter on which it must be admitted we know little at present. That it is a unit character is perhaps indicated by the fact that some varieties are consistently heavier yielders than others even under a wide range of variation in the conditions. For instance, Square Head's Master has, on this account, gradually driven such varieties as Red Lammas, Chiddam, Talavera, &c., practically out of existence. Further, the cultivation of a long series of hybrids between heavy and comparatively low yielding wheats seems to point to segregation of these features. Exact statistics, however, are very difficult to obtain owing to the wide range of fluctuating variability in this character and the difficulty of growing plants under sufficiently uniform conditions to eliminate this. Even when the outer rows of an $F._2$ culture are neglected as consisting of obviously favoured plants, gaps, due to failures in germination or the attacks of mice, &c., give neighbouring plants a greater root range and better opportunities for development than others. In the absence of such information one has to fall back on the yields of the plots grown from the $F._2$ generation and then on the crops of succeeding years, basing conclusions as far as possible on plots of sufficient acreage to give trustworthy returns. For this purpose the Fife hybrids mentioned previously are fairly suitable, as under the conditions under which these experiments were made Fife barely yields twenty bushels to the acre, whilst Rough Chaff may be expected to give a good average yield of thirty-two bushels.

In making the selections for further cultivation these strong types, promising to give the best yield, were deliberately chosen. Some forty of these, which have been tested in plots varying from one-quarter to three acres in extent, have given in each case yields of the same order as the parent Rough Chaff and over 50 per cent. greater than Red Fife on the same farm. On other soils some grown on the large scale have produced crops of forty-two to forty-four bushels, but in these cases the cropping capacity of Rough Chaff is unknown, though Fife is known to be a failure as regards yield. The evidence for the segregation of high and low yields is by no means final, but it is sufficient to show that high yields of good quality are not unobtainable.

The question of heavy yields per acre is intimately connected with the power of resisting the various diseases to which the wheat crop is liable, as no plant crippled by the attacks of a parasite can be expected to yield its full quantity of grain. It is a well-known fact that if a large number of varieties of any plant grown under the same conditions are exposed to the same chances of infection they show marked differences in the extent to which they become attacked by various parasites. This is well shown in the case of wheats and the various rusts which live upon them. In fact, it has now become part of the routine work of many experimental stations to collect and grow as many varieties as possible, with the view of selecting the most immune types for local cultivation. In our earlier tests several varieties were found showing an extraordinary power of resisting the attacks of the common yellow rust, *Puccinia glumarum*. Even in years when the rust attack has been at its worst they have shown only the merest traces of infection. Such immune varieties were at once crossed both with moderately

and with extremely susceptible varieties to determine whether the power of resisting disease would prove a unit character. In each case the hybrid plant proved susceptible to yellow rust, whilst its offspring consisted of immune and susceptible forms in the proportion of one of the former to three of the latter. In the many cases examined the segregation has proved to be exceedingly sharp. The property of resisting the attacks of yellow rust is thus shown to be a Mendelian recessive, and consequently all extracted immunes should breed true to this feature in succeeding generations. This point has now been tested many times, with concordant results in all cases. Further, the experiments have shown that immunity is independent of any recognisable morphological characters. Thus in the case of yellow rust there appears to be no valid reason why the plant breeder should not mitigate the evils of its attacks by using this knowledge as a basis for the production of resistant varieties. The attempts already made seem to show conclusively that this is practical. One example must suffice. From a cross between Square Head's Master and a resistant variety found in Russian Ghirka wheat two very promising wheats, one immune and one susceptible, were isolated and grown on for comparison. In 1909, a moderately bad rust year, three-acre plots of these varieties were grown alongside one another. The susceptible variety gave one of the most striking plots of wheat on the experimental farm; the immune variety also grew into a good crop, though farmers visiting the station almost invariably preferred the former, in spite of its rustiness. At thrashing time, however, the effects of the attack became obvious, as the susceptible variety only yielded some forty-two bushels of grain per acre, as compared with fifty-four bushels per acre from the immune variety. The grain of the former was also so shrivelled that it was only fit for chicken food, whilst from the latter less than a half per cent. could be screened when dressing it for seed.

If the attacks of yellow rust can be controlled in this manner it is reasonable to suppose that the still more serious black rust (*Puccinia graminis*) can also be brought under control. At the present time the most that can be said is that some evidence pointing in this direction has been obtained. The problem will, however, have to be solved elsewhere, for even with plantations of the alternative host, the Barberry, in the vicinity of the trial plots, we cannot count on a yearly epidemic of this rust to test the varieties thoroughly.

4. *Wheat Breeding in Canada. By* CHARLES E. SAUNDERS, *Ph.D., Cerealist of the Dominion Experimental Farms.*

On account of the vast extent and the varied climatic conditions of Canada, it is necessary to mention briefly the six chief sections into which the country may be divided on the basis of its wheat production.

I. *The Maritime Provinces: Nova Scotia, Prince Edward Island, and New Brunswick.*—In these large tracts of country not very much wheat is grown. Most of the grain is sown in the spring, and the yields obtained are usually good, the kernels being plump, but rather soft and starchy.

II. *Quebec and Northern Ontario.*—Spring wheat rather than winter wheat is usually grown, although the total quantity produced is not very great considering the numerical strength of the farming population. The kernels of the spring wheat produced in this section of Canada are usually somewhat smaller and harder than those grown in the Maritime Provinces. When the varieties which yield the strongest flour are sown, the wheat from this area is scarcely surpassed by that grown in any other part of Canada, though in appearance it is usually less attractive than the grain from the Western prairies.

III. *Southern Ontario.*—The mild winter and the rather hot and dry summer make the conditions in this region more favourable to winter wheat than to spring wheat. Most of the sowing is therefore done in the autumn, September and October being the favourite months. The winter wheat of Southern Ontario is typically large, plump, and quite starchy. When spring wheat is sown a variety of durum wheat known in Canada as 'Goose' or 'Wild Goose' is often used because it gives a better yield than the ordinary varieties used for bread-making. Goose wheat is used chiefly for feeding purposes or for the manufacture of macaroni.

IV. *Manitoba, Saskatchewan, and the Northern and Central Parts of Alberta.*—This enormous tract of country is devoted very largely to the cultivation of spring wheat, which, as a rule, gives a good yield and produces kernels of a hard, glutinous character scarcely to be surpassed. Winter wheat has been tried in some sections but has not proved uniformly successful.

V. *Southern Alberta.*—Winter wheat has been profitably grown for many years in the south-western portion of Alberta, and the area devoted to it of late has been largely extended northwards and eastwards. Spring wheat is also grown in this portion of the Province but to a smaller extent than winter wheat. The yield per acre of winter wheat is usually large and the kernels are exceptionally heavy and hard.

VI. *British Columbia.*—This Province does not produce very much wheat, though it is found profitable where grown. Both winter and spring varieties are sown. The diversity of climates in this Province is so great as to render impossible any general descriptive remarks on the subject.

From the details just given it will be readily seen that the position of winter wheat in Canada is distinctly subordinate to that of spring wheat. In order, therefore, to bring the subject within reasonable limits all discussion of the work which has been done in this country with winter wheat is omitted.

Most of the breeding and selecting of varieties of wheat in connection with the Dominion Experimental Farm system has been carried on at the Central Farm at Ottawa, where the climate in many respects resembles that of most of the spring wheat districts of Canada. The selections made at the Ottawa Farm are only provisional; the most promising varieties are afterwards sent to the various branch farms for further trial and for the rejection of any found unsuited to the local conditions.

When the Dominion Experimental Farms were first established the settlement of the great prairie country of Central and Western Canada had not progressed very far, so that there were various problems of vital importance connected with the growing of wheat on the plains which awaited investigation. While, therefore, the needs of the older farming districts have not been overlooked, the most interesting branches of the work have been those concerning the great wheat-growing plains. The short summer of the prairies emphasised the need for early-maturing varieties of wheat, while the long distance between the farmer and the main centres of wheat consumption made it essential that only such varieties should be grown as would command an exceptionally high price in the world's markets, so that the cost of transporting the grain would be relatively low.

The prairie settlers found the famous Red Fife wheat very satisfactory on the whole, except in regard to the time taken to mature the crop, which in the less favourable seasons was rather too long; so that the fields were sometimes touched with frost before the grain was ready to be cut, thus very seriously lessening the farmers' income. In hardness of kernel and in flour strength (the characteristics which perhaps chiefly determine the selling price of any wheat) this variety ranks at the head of its class.

What was needed, therefore, for the great wheat-growing plains was an early Red Fife: a variety having all the good qualities of ordinary Red Fife with the added excellence of earliness.

To meet this need, early-ripening varieties of wheat were imported from various countries by the Director of the Experimental Farms, and at as early a date as possible experiments in cross-breeding were begun for the purpose of combining in one sort all the desired qualities. Naturally, Red Fife was used as one of the parents in the majority of the crosses which were effected, as this wheat perhaps possesses more good points than any other well-known kind from a commercial point of view.

None of the early wheats imported from other countries proved satisfactory for our conditions, although some of them have been found of great value in cross-breeding. The new and improved varieties which have been or are being given to the public have therefore been produced either by cross-breeding (followed by selection) or by the mere selection of superior strains from existing sorts. Both of these lines of work have given valuable results, though selection alone has been found to be limited in its practical possibilities.

The work of cross-breeding was begun by Dr. William Saunders (the Director of the Experimental Farms) and his assistants in the year 1888. The principal crosses which were made at that time were between Red Fife wheat (or White Fife, an almost identical sort) and an early-ripening variety which had been obtained from Russia. Some years later other crosses were effected, but the main interest has centred in the progeny of the first crosses, especially those known as Stanley, Preston and Huron, which are now widely distributed throughout the western provinces and which have contributed largely to successful wheat-growing in many of the less-favoured localities during the past few years.

In the earlier years the system of selection after crossing was not so thorough as that now known to be necessary. The cross-bred varieties first introduced were therefore not quite fixed in some essential respects; and it devolved on the writer of this Paper, who was appointed in the year 1903 to take charge of the work with cereals, to re-select all the varieties of wheat obtained from the crosses effected up to that time. By this re-selection, on Mendelian lines, of course the early cross-bred wheats have been distinctly improved; the best of the new, selected strains combine to a very large extent the good qualities of both parents. Stanley, Preston and Huron, as now grown at the experimental farms, are vigorous, early sorts, ripening a few days—or sometimes nearly two weeks—before Red Fife, and having hard, bright kernels of the popular reddish-brown shade. In yield of grain per acre they often surpass Red Fife, even when the conditions are favourable to the latter sort, and in yield of flour in the mill they are quite satisfactory. From a commercial point of view they are all somewhat inferior to Red Fife, for while they produce flour of good quality it does not usually possess the remarkable baking strength which generally characterises Red Fife flour. Preston and Huron have a further but not very serious disadvantage of yielding flour of a deeper yellowish colour than that made from Red Fife. Stanley gives flour of the same shade as Red Fife.

In addition to the three new varieties just mentioned, which inherited their early-maturing qualities from a wheat from Northern Russia, reference should be made to three other cross-bred sorts, Marquis, Chelsea and Bishop, which owe their earliness largely to the fact that one of the parents in each case was a very early wheat obtained from India. Marquis and Chelsea are descended in part from Red Fife. Bishop is an Indo-Russian cross. Of these newer varieties Marquis is perhaps the most important, showing distinct superiority over the cross-bred varieties first introduced

in regard to the character of the flour, which both in strength and in colour is practically identical with Red Fife. Comparative baking tests carried on last winter with samples from the crop of 1908 showed that Marquis grown at Brandon, Manitoba, was equal in colour and strength of flour to Red Fife grown on the same farm, and was superior to Red Fife grown at Indian Head, Saskatchewan. The differences observed were not very great and might perhaps be reversed another season; but the high strength of Marquis is fully established by these and previous tests. Marquis is a beardless wheat having hard red kernels and resembling Red Fife in all respects, except that it is earlier in ripening. It ripens about with Stanley, Preston and Huron.

Chelsea is a very early, beardless wheat, satisfactory in all respects except flour strength, in regard to which it ranks about with Stanley and Preston. It closely resembles the new, selected strain of Stanley, but seems to be earlier and perhaps more productive than that variety.

Bishop is a still earlier wheat, possessing many good qualities, its remarkable productiveness being of special interest. It gives a rich-looking, yellowish flour of good strength, but not equal to the strongest varieties. In spite of its many admirable qualities the fact that it possesses a pale, yellowish skin prevents us from advising farmers to grow it for export; the Canadian grain inspection laws are based on the idea that wheats with a pale skin are usually of inferior quality, and the regulations in regard to the grading are so worded as to make it practically impossible for any farmer to obtain a fair price for a yellow (or so-called 'white') wheat in what is known as the Manitoba Inspection Division. Bishop has succeeded remarkably well at almost all points where it has been tested. As an instance of special interest I may mention that a large yield per acre of grain weighing 65 lbs. to the measured bushel was obtained from this variety last season at Lesser Slave Lake in a latitude about 400 miles farther north than Winnipeg. No doubt it will succeed very well much farther north than this.

These new varieties and new strains of the older sorts are now being propagated for free distribution. Most of them were available to a limited extent for that purpose last winter. At present it appears that Marquis may take the lead as the best for export purposes of all the early sorts yet introduced, unless the selected form of Red Fife, mentioned later in this paper, should prove equally early. These two varieties are very much alike, though of quite distinct origin.

In addition to the six varieties of wheat mentioned by name, which have all sprung from crosses made in the earlier years of the existence of the experimental farms, we have now on hand a large number of very promising varieties which have been produced from crosses made by the writer in more recent years. About 200 of these new sorts are now being propagated for further test and will probably soon be followed by several hundred others, from the progeny of the most recent crosses which at the present time are not quite fixed in type. Of course it is not intended to retain more than a few new varieties adapted to the various conditions of soil and climate in Canada. The task of eliminating the less desirable sorts will therefore be rather lengthy and difficult, especially as the baking strength of the flour must be considered in nearly all cases.

When this work was commenced, the strength of the flour from any wheat could not be determined until a large quantity of grain was available, and even then we were dependent on the mere opinion of some commercial baker, not usually a trained scientist, as to the characteristics and value of the flour. Now, however, with the introduction of the small experimental flour-mill and the development of a scientific method of determining baking strength, this matter can be investigated much earlier

in the history of each variety; the conclusions reached are far more trustworthy than before. All new varieties intended for bread-making are tested in the baking laboratory before being distributed. In addition to the final baking tests I have used for several years a simple chewing test (taking only a few kernels of wheat) as a valuable guide to gluten strength and probable baking strength in the earlier stages of selection. This test was advocated as an essential aid in the selection of cross-bred varieties of wheat in the Bulletin on Quality in Wheat, published at Ottawa, October 1907.

Results of considerable practical importance have already followed the introduction of these early maturing wheats, since they can be depended upon to ripen in some districts where the old standard variety Red Fife is often caught by frost. By the use of these earlier kinds the areas of profitable wheat culture have been extended. Furthermore, a small acreage of some of the new sorts may be advantageously sown, especially on stubble land, even districts where Red Fife succeeds fairly well, so as to lengthen the harvesting season when labour is scarce; with the possible exception of Marquis, however, none of the new cross-bred sorts thus far introduced can be recommended in place of Red Fife in localities where that variety can usually be ripened.

As an instructive proof of the value of early-maturing wheats some results obtained last season on the experimental farm at Lacombe in Central Alberta may be cited. All the spring wheat on that farm was somewhat blemished by frost with the exception of one very early variety, Downy Riga, which was cut before the first frost. The kernels were plump and bright with a smooth skin, and weighed 63½ lbs. to the measured bushel. Huron, a little less early, was still so well advanced at the time of the frost that the kernels when threshed were plump and weighed 62 lb. to the measured bushel. The bran, however, was so much roughened by the frost that the wheat would have been graded quite low if offered for sale. Red Fife from the same series of plots was very seriously damaged by the frost, the kernels being rather shrivelled and the bran somewhat rough. The weight of a measured bushel was only 58½ lbs.; the yield 18 bushels per acre. Downy Riga gave 31 bushels and Huron 37½ bushels per acre.

While the results achieved thus far are of great value, still further advances are expected in the near future. Some of the new, hard, red, early wheats derived from the writer's recent crosses are to be ground and baked during the coming winter; it is expected that from fifty to a hundred new sorts will be tested in this way every year for several years to come. Out of this large number we may confidently look forward to the discovery of at least a few varieties which will surpass any of those yet known by combining all the good qualities needed in an early maturing wheat for export.

Though cross-breeding is essential for the production of new varieties of wheat radically distinct from any existing sorts, one may occasionally isolate by mere selection some fairly distinct type (a 'sport' or a 'mutant') superior in certain respects to the variety from which it was selected. A considerable amount of selection has been carried on at Ottawa, and one at least of the new strains discovered promises to be of importance and ranks in interest with the cross-bred sorts. This is a strain of Red Fife wheat originated from a single early maturing plant found by the writer in 1903. This strain has been thoroughly tested both in the field and in the baking laboratory, and has been proved to be genuine Red Fife in all essential respects. It ripens earlier and shows certain other minor points of difference, but would be generally recognised as Red Fife. This wheat has now been grown for six years at Ottawa and was tested

during the present season at Brandon also; it is a strong grower and promises well. Its advantage in earliness over common Red Fife is only a few days under ordinary conditions; by no means sufficient to meet the needs of all districts, but quite enough to establish its value and to create a large demand for it. It has been named Early Red Fife and will, it is expected, be available for general distribution in small quantities after the next harvest.

It would be quite in accord with popular ideas if we were to carry on repeated selections of Early Red Fife for earliness through several years or decades, in the hope of obtaining still further advances in that direction. Unfortunately there are good grounds for believing that the further advances would 'tease the patience of the centuries' before any striking results would be obtained. Early Red Fife did not, in all probability, acquire its earliness by degrees but at one step, at the same time as its other points of difference from the parent variety were manifested. In introducing this variety I do not claim that I have *improved* Red Fife wheat, but that I have discovered and isolated an improved type which had previously been mixed with the ordinary form. It is from cross-breeding followed by selection that one may expect the greatest advances in the direction of any desired change; and it is to cross-bred varieties therefore that we must look for still earlier wheats of high baking strength.

We may now turn to some of the observations of a scientific character which have been made during the progress of this work.

In regard to the inheritance of awns I wish merely to repeat my view that awns and the absence of awns do not necessarily form a pair of Mendelian unit characters, but that an intermediate condition is quite common (in wheats of cross-bred origin) in the first generation and also in succeeding generations. It has been asserted that strength and weakness of flour form a pair of Mendelian unit characters. Even after making all due allowance for the necessarily somewhat indefinite meaning of the words *strong* and *weak*, the writer finds it impossible to accept this view. (See *Journal of Agricultural Science*, vol. iii. p. 218.)

Among other irregularities in inheritance, two may be mentioned which occur so frequently as to suggest that they may perhaps be *regularities* after all. When two varieties of wheat having reddish bran are crossed, it often occurs that in the second and later generations some of the progeny have yellowish bran. In regard to awns a somewhat similar phenomenon is often observed, namely, the appearance in the second and later generations of fully bearded plants, both the parent varieties having been practically awnless. In such cases I have never witnessed the production of intermediate or half-bearded types which are so common when bearded and beardless sorts are crossed. Perhaps the occasional production of downy chaff when two varieties with smooth chaff have been crossed may also belong to this same category, though it appears to be less common.

---

5. *The Influence of Good Seed in Wheat Production.* By C. A. ZAVITZ, *Professor of Field Husbandry, Agricultural College, Guelph, Ontario.*

That good seed is at the very foundation of good farming is as true in the case of wheat as it is in that of any other farm crop; seed is therefore occupying the attention of investigators throughout the world. When we realise that about 11 per cent. of all the wheat grown, amounting to fully 300 million bushels, is used annually for seed, we can understand something of the great importance of the problems.

A considerable amount of attention has been paid to the study of the seed of various classes of farm crops, including wheat, at the Agricultural

College, Guelph, Ontario, during the past twenty years, but more particularly during the past ten years. Both winter wheats and spring wheats are grown in the province, the former the more extensively. The grain of the common wheats is principally used for the manufacture of bread, of pastry and of breakfast foods; that of the durum, or the macaroni wheats, for flour to mix with that of the softer winter wheats and for export to other countries; and the Emmer as feed for farm stock. This paper will be confined almost entirely to results of experiments conducted at the Ontario Agricultural College on the seed of the common wheat (*Triticum vulgare*).

About fifty acres of land, divided into upwards of two thousand plots, are used for experiments with farm crops. The grounds have a gentle slope towards the south-west; the soil is an average clay loam. A four years' rotation, consisting of grain, cultivated crops, grain and pasture, is adopted. Twenty tons of farmyard manure per acre are applied once every four years before the cultivated crops are grown. No commercial fertilisers are used except in distinct fertiliser experiments, to which only a small number of plots is devoted each year. The plots vary in size, according to the requirements of the different experiments; the yields per acre are determined from the actual yields of the plots in every instance. All of the experiments are conducted for at least five years; many of them are continued for a much longer period of time.

Varieties of Common Wheat (Triticum vulgare).

Three hundred and seventy-three varieties of wheat have been tested for at least five years. Those which have made high records at the College have also given good returns in the co-operative experiments conducted throughout Ontario on hundreds, and even thousands, of farms. It is interesting to note that those varieties which took the lead in the experiments at the College, and were distributed for the co-operative experiments several years ago, are the most extensively grown varieties in the province at the present time. Other varieties of high quality are now being used both for distribution and as foundation material for plant breeding.

When tested under uniform conditions of soil and climate, it is found that certain wheats are particularly strong in some respects and comparatively weak in others. In order to secure a wheat best suited for the locality in which it is to be grown, it is necessary to have a proper blending of such valuable characteristics as strength of straw, yield per acre, quality of grain, &c. The differences in the varieties are shown in Table 1, giving the average results of twelve varieties of winter wheat and twelve of spring wheat which have been tested at the Ontario Agricultural College for several years in succession. The varieties selected in each class are those which have given the largest average yields of grain per acre, as determined on the experimental plots.

Dawson's Golden Chaff stands highest in average yield of grain per acre of the fifteen varieties of winter wheat tested in each of fourteen years. It produces a very stiff straw of medium length, beardless heads with red chaff and white grain somewhat soft, but slightly over the standard in weight per measured bushel. The Early Genesee Giant furnishes a straw of medium length and of fair strength, a short, compact, bearded head and a grain of fairly good quality. The Imperial Amber produces a large amount of straw which is somewhat weak, a bearded head, red chaff and a red grain of average quality. The Geneva, the Tasmania Red and the Turkey Red varieties yield about ten bushels per acre per annum less than the Dawson's Golden Chaff and possess comparatively weak straw, but the grain is hard, weighs well per measured bushel and produces large

Average Results of Each of Twelve Varieties of Winter Wheat.

Varieties	Bearded or Beardless Heads	White or Red Chaff	White or Red Grain	Per cent. of Rust, 6 Years	Per cent. of Crop Lodged, 6 Years	Comparative Hardness of Grain, 3 Years	Pounds per Measured Bushel, 13 Yrs.	Yields per Acre, 14 Years	
								Straw	Grain
								Tons	Bushels
Dawson's Golden Chaff	Ba	R	W	7	0	65	60·2	3·2	54·8
Early Genesee Giant	Be	R	W	10	11	72	60·4	3·3	50·4
Imperial Amber	Be	R	R	6	16	72	61·1	3·4	49·6
Russian Amber	Be	W	R	7	7	72	61·3	3·4	48·9
Egyptian Amber	Be	W	R	7	7	69	61·7	3·4	48·4
Early Red Clawson	Ba	R	R	7	12	69	59·4	3·0	48·1
Rudy	Be	W	R	7	10	76	61·3	2·8	46·4
Geneva	Be	W	R	8	18	79	62·5	3·1	45·1
Tasmania Red	Be	R	R	7	18	88	61·9	3·1	44·7
Turkey Red	Be	W	R	8	10	98	61·6	2·9	44 7
Kentucky Giant	Be	W	R	7	9	83	61·5	3·0	44·7
Treadwell	Be	W	W	5	6	71	60·9	3·0	44·6

Average Results of Each of Twelve Varieties of Spring Wheat.

Varieties	Bearded or Beardless Heads	White or Red Chaff	White or Red Grain	Inches in Height, 5 Yrs.	Per cent. of Rust, 5 Years	Days to Reach Maturity, 5 Years	Pounds per Measured Bushel, 5 Years	Yield per Acre, 5 Years	
								Straw	Grain
								Tons	Bushels
Minnesota No. 163	Ba	W	R	46	6	121	58·9	2·2	34·1
Hungarian Red	Be	R	R	41	5	116	62·1	2·1	33·6
Climax	Be	W	R	47	6	119	59·1	2·1	31·9
Carleton	Be	W	R	47	9	120	59·3	2·2	31·4
Red Fife	Ba	W	R	45	8	120	58·2	2·1	31·3
Saxonka	Be	W	R	46	6	119	59·8	2·0	31·2
White Russian	Ba	W	R	43	9	121	58·0	1·9	31·0
Blue Democrat	Be	W	R	46	9	119	58·9	2·1	30·8
Preston	Be	R	R	43	10	115	59·1	1·8	30·8
Wellman Fife	Ba	W	R	45	11	120	57·5	2·1	30·5
Kolben	Ba	W	R	44	7	121	59·2	2·0	30·1
Herison Bearded	Be	R	R	43	7	118	61·8	2·0	30·1

Ba = beardless. Be = bearded.

loaves of bread of good texture. The Crimean Red variety of winter wheat, which has been imported more recently, surpasses the Turkey Red in both yield and quality of grain, but the Crimean Red is even weaker in the straw than the Turkey Red.

Minnesota No. 163 occupies the highest place in yield of grain per acre among the varieties of spring wheat tested at the College for five years. Its grain weighs rather light per measured bushel but has given very good results in bread-making. The Hungarian Red variety of spring wheat, which has surpassed the Red Fife by an average of 2·2 bushels of grain per acre and by 3·9 lb. in weight of grain per measured bushel, has also been superior to the Ontario-grown Red Fife for bread and has reached maturity four days earlier. The Hungarian Red wheat was imported by the Ontario Agricultural College from the Argentine Republic in the spring of 1903. It was distributed along with Red Fife throughout Ontario in the spring of 1908 for co-operative experiments, and proved to be superior to Red Fife both in yield of grain and straw per acre and in popularity with the experimenters. It certainly shows some strong features as foundation stock for plant breeding.

Selection of Seed.

Within the past fourteen years a large amount of experimental work has been done to determine the influence of different selections of seed upon the resulting crop. For the wheat experiments, fresh seed was taken each year from the general crop of grain grown in the large fields. The results therefore represent simply the one year's influence from seed selection, but the experiments were repeated from season to season so as to secure a good average of conditions of soil, temperature and rainfall. For the large sample, none but well-developed seeds were selected; for the small sample, none but sound, plump and comparatively good seeds of small size were used; for the shrunken sample, none but shrunken grains of good size were selected; and for the broken sample, none but seeds which had been broken by the threshing machine were included. The selections were made with great care by the use of sieves and then by hand-picking the seeds. A quantity of the large, plump grains sufficient to sow a plot twenty-five links square was carefully weighed out and the grains were then counted. A corresponding number was then taken of the small, the plump, the shrunken and the broken seeds. The different lots were sown upon plots made as uniform as possible. The following table gives the average results obtained from the various selections of both winter wheat and spring wheat:—

Crops	Average Annual Yield of Grain per Acre (Bushels)				
	Number of Years Tested	Large Seed	Small Seed	Shrunken Seed	Broken Seed
Winter wheat .	6	46·9	40·4	39·1	9·3
Spring wheat .	8	21·7	18·0	16·7	—

The results of the twelve separate tests made at the Ontario Agricultural College with winter wheat show an average increase in yield of grain per acre of 6·5 bushels from large, as compared with small seed; of 7·8 bushels from plump, as compared with shrunken seed; and of 35·6 bushels from sound, as compared with broken seed; in sixteen separate tests with spring wheat, of 3·7 bushels from large, as compared with small seed; and of 5 bushels from plump, as compared with shrunken seed.

In the average of five years' experiments with winter wheat, seed which was allowed to become thoroughly ripened before it was cut produced a greater yield of both grain and straw and a heavier weight of grain per measured bushel than that produced from grain cut at any one of four earlier stages of maturity.

Occasionally in Ontario the rains are so abundant at the time of harvesting the wheat crop that the grain becomes sprouted more or less in the shock or even before it has been cut. As the crop dries, germination is checked and the grain hardens. It is often a question as to whether such grain which has thus started to germinate is as valuable for seed purposes as that which was secured without becoming sprouted. In each of two different years very careful germination tests were made at the College of winter wheat which was out during wet weather and which became more or less sprouted. Several varieties were used each year. The average percentages of germination were as follows: Seed which showed no outward sign of germination, 94; seed slightly sprouted, 76; seed considerably sprouted, 30; and seed badly sprouted, 18. It will therefore be seen that sprouting injures the grain a great deal for seed purposes. When the grains are badly sprouted, fully four-fifths of them decay in the ground; those which do germinate afford very uneven plants.

From the results of experiments here presented in the selection of seed, we see clearly the advantage of sowing large, plump, sound, well-matured seed of strong vitality if the best results are to be obtained.

The Improvement of Wheat by Systematic Selection and by Cross-fertilisation.

A careful study of a large number of varieties of wheat for several years in succession furnishes excellent foundation stock for work in plant breeding. For a number of years past, particularly since 1902, a considerable amount of work has been done at the Ontario Agricultural College in the hope of improving some of the best varieties of wheat through selection and through cross-fertilisation. Selections have been made of the Dawson's Golden Chaff, Imperial Amber, Bulgarian and Turkey Red varieties of winter wheat and of the Red Fife variety of spring wheat. Some of these selections have been made by using choice heads obtained from the large fields, others by using superior plants obtained from about nine thousand plants of each variety, the seed of which was planted in rows one foot apart, the plants being one link apart in the rows. For sowing in rows the following year, the best quality of seed from the selected plants was used. The seed from those strains which produced the best results in the rows was used for both rows and small plots in the year following. In the next year, the seed of strains giving the best results both in the rows and in the small plots was sown in rows, in small plots and in larger plots, so that the results of the new strains could be compared with those of the standard varieties. We have thus been able to obtain strains giving larger yields of grain of better quality than the original varieties. Especially has this been true with Dawson's Golden Chaff, the Bulgarian, and the Turkey Red.

With the object of combining the good qualities and eliminating the undesirable characteristics of the leading varieties of wheat, work in hybridisation was started in 1902 and has been continued each year since that date. Crosses have been made between the Dawson's Golden Chaff and the Turkey Red, the Bulgarian, the Tasmania Red, the Buda Pesth, the Geneva and the Imperial Amber varieties of winter wheat; between the Bulgarian and the Turkey Red varieties of winter wheat; between the Red Fife spring wheat and the Turkey Red winter wheat; between the Red Fife and the Herison Bearded varieties of spring wheat; and between the Red Fife spring wheat and the Wild Goose and the Medeah varieties of durum wheat. In 1909 no less than 21,365 hybrid plants of winter wheat and 32,698 hybrid plants of spring wheat were grown separately in the experimental grounds. Besides these, fifty-nine plots of winter wheat and seventeen plots of spring wheat hybrids were under test. The results obtained are exceedingly interesting and very promising. To give these results even in concise form would require a lengthy paper in itself. In connection with this work we are exceedingly grateful for the information and the inspiration of such men as Gregor Mendel, Dr. de Vries, Dr. Nillson, Prof. Bateson, Dr. Wm. Saunders, and others. The writer firmly believes that there was never a time in which the outlook for the work in plant breeding was as promising as it is at present. Good seed has a meaning far deeper and far more significant than many of us have realised in the past.

---

6. *Individuality in Plants. By* L. S. KLINCK, *Macdonald College, Quebec, Canada.*

No two plants are exactly alike. Indeed, a close study of thousands of individuals reveals striking differences, not only between plants of the

same species but even between individuals of the same variety. The majority of plants constituting improved varieties of cereals, in this country, reveal on close examination striking morphological and substantive differences.

Morphological differences are most readily noticed. Each plant in a plot of thousands may have its own individuality and still bear unmistakable evidence of belonging to the same variety. Substantive differences, on the other hand, are more subtle. In individual plants these qualities cannot be measured, weighed, or accurately determined. Knowledge of correlations may be of service in helping to arrive at a decision, but the ability of a plant to transmit its characters must be the final test. The closest study of the physical characters of a number of plants, with a view to securing uniformity in general conformation, will come far short of enabling the breeder to determine the projected efficiency of the individuals under consideration. Such information can be obtained only by testing separately the progeny of each plant under conditions as nearly uniform as possible.

For this purpose the centgener system was devised—a system which renders possible the testing of a large number of mother plants whereby a record of the performance of each plant is obtained. The plant is the unit of selection. The centgener is a trial plot of one hundred grains planted from the product of a single mother.

A prime requisite in planting a foundation bed from which mothers are to be selected is to have all the plants grown under conditions as nearly the same as possible. To secure this equality of opportunity, so far as external conditions can be controlled, carefully chosen grains taken from hand-selected heads of the most promising varieties are planted in foundation beds four inches apart each way. The plants resulting from this seeding are pulled and studied separately in the field at harvest time and are subsequently subjected to a more severe test in the laboratory. So rigorous is this selection, based on the physical characters of the plants, that not more than one in five hundred is considered eligible for trial in the centgeners. The same fundamental tests are applied to the centgeners as were applied the previous year to the individual plants in the foundation beds. This reduces the number eligible for registration to one in one thousand, and frequently this proportion cannot be had. Full notes are taken on the centgeners in the field, and the next season multiplying plots are sown broadcast from those centgeners which have the best performance record. In the fifth year the product of the multiplying plots enters into competition with the original variety. If, in this contest, it proves superior to the original stock it will be multiplied on the general farm as rapidly as possible and sold to the farmers at a reasonable price.

In our work so far, numerous variations, some desirable and many undesirable, have been isolated from the 550,000 plants studied during the past three years. The progeny of many of these mothers has differed widely from the parent plant and consequently from each other; the progeny of each mother from the best plants has always been remarkably uniform within itself, and, with few exceptions, which we have not as yet proven to our satisfaction, has come true in the multiplying plots. In well-established varieties of oats of known breeding and purity, some strains have been isolated which ripened two weeks before others, and equally striking differences have been observed and perpetuated. This holds true under practically every heading under which oats are judged in the field or in the laboratory. Even among the most productive individuals the range in yield is surprising, the area covered in the third generation from one kernel of Joanette oats in one case being 127·78 square feet and in the other 0·89 square foot, one 144 times the other. The latter, in addition to being a very low-yielding strain, was also very poor in quality.

While equally striking differences have not been discovered in wheat, barley, emmer, spelt, peas, soy beans, or corn, the range has been remarkably wide in all of these classes. The purest strain of Mensury barley obtainable has yielded a number of distinct types with widely different characters, which have so far given every evidence of high yield and fixity of type. The outstanding point, which even the most casual observer never fails to note, is the remarkable uniformity which characterises the different strains, while length of straw, time of ripening and general conformation make their appeal to the eye of the cerealist.

From our work we are not prepared to say that this remarkable uniformity will continue. Sufficient work has been done to direct attention to the need of a more careful study of the individuality of plants and to emphasise the still more important point that this range is as wide in the projected efficiency of the plants as it is in the morphological differences. It may also be of service in drawing attention to the necessity of obtaining fuller knowledge of the parentage of plants mated before breeding is undertaken by crossing or by hybridising.

---

7. *Quality in Wheaten Flour.* *By* A. E. Humphries.

Good quality is an outcome of excellence in several respects; these have been stated to be strength, colour, flavour. This list, however, should be extended to cover at least five qualities, as the term 'strength' frequently includes (*a*) 'stability,' which should be taken to indicate the facility with which large masses of dough can be handled in the bakehouse; (*b*) the capacity for making a large quantity of bread from a given weight of flour; (*c*) the size and shape of loaf.

These subdivisions of 'strength' should be regarded as essentially different characteristics, frequently combined in the same flour but in reality independent units of quality. Strength should be defined as 'the capacity for making large, shapely and, therefore, well-aerated loaves.' High dietetic value is the result of the proper combination of various qualities and need not therefore be specified as a separate characteristic.

It should be remembered that in the economy of Nature wheat is a seed. The true function of the husk is to protect the food of the plantlet, and it therefore resists disintegration and can be found in existence in the ground six or nine months after planting. The endosperm or kernel is converted by the action of enzymes, operating on a damp or wet pabulum, into the food of the plantlet until the latter is able to get its sustenance from soil and air. These agents and operations have to be controlled or influenced by the miller and baker when wheats and wheaten flour are diverted from their natural functions to use as food for man.

Flavour.—If an extremely small proportion of diastase—say 0.02 per cent. of absolute diastase or its equivalent in the malt extracts of commerce—be added to flour in milling or in baking, a very perceptible improvement in flavour is produced. If sugar itself be added its effect on flavour is either *nil* or harmful. It seems, therefore, that the improvement in flavour due to the addition of diastase is caused by the production in fermentation of intermediate products of a dextrinous nature. An improvement in flavour is usually or frequently correlated with an increased moistness of the bread. The water-retaining capacity of dextrinous matter is well known. One charge against modern milling is that the germ of wheat is now extracted. In a Paper ('Modern Developments of Flour Milling') read before the Royal Society of Arts in 1906 the author showed that a substantial proportion of the germ was extracted by millstone milling, but a larger proportion is extracted by roller milling. The percentage of the

wheat extracted as germ by either process is very small, but as a consequence enzymic action is diminished to an appreciable extent. Some harm is also done to flavour, but, on the whole, it is desirable to extract the germ. Enzymic action depends not only upon the presence of enzymes in sufficient quantity but upon the physical state of their pabulum. The methods of milling, in particular the skilful use of water in conditioning the wheat before grinding or in the processes of grinding and separating, or even the addition of water by the miller to certain flours after milling, may materially assist enzymic action.

Colour.—Opinions differ as to whether perfection of colour implies whiteness of chalky or of creamy hue; all are agreed it should imply brightness of appearance in crumb and crust. Excellence of colour in bread cannot be measured by any absolute colour standard. It is largely a question of optics. Refraction and reflection of light most materially affect the judgment of the observer in looking at a loaf of bread. A flour which is white or even very white but weak may make puddings of good colour, but loaves of poor dingy appearance. However, if an improved aeration be effected, either by successful treatment of the flour by the miller or baker or even by the admixture of some stronger darker flour, the resulting bread is made to appear much whiter. The causes which affect colour in flour do not seem to have been definitely determined. Modern developments of flour milling have eliminated dirt and dark fungoid contamination and in increasing degree are still diminishing the amount and intensity of friction in milling, whereby discoloration due to the pulverising of the husk is diminished. It is desirable to obtain a more thorough acquaintance with the colouring matter of wheat and flour to know with more precision what it is, how it is distributed by Nature in wheat and what happens to it in milling.

Scientific and milling circles have been much exercised as to whether artificial bleaching of flour is due to nitrating or oxidising or to both. Chemists should consider the point why the addition of alkali turns some flours yellow and why the addition of acid or acid salts has sometimes a whitening effect.

Cerealists and chemists might jointly consider whether it is a fact that climate materially affects the colour of wheat; for instance, whether a red-skinned wheat grown in California does in fact become white-skinned after a few seasons there, and if so what change has been effected in the nature and distribution in the berry of the colouring matter.

Strength (Size and Shape of Loaf).—In most cases a large loaf is an indication of the high gas-yielding capacity of the flour from which it is made, and is ordinarily also an indication of high diastatic power. A 2-lb. loaf measuring 3000 c.c. is better aerated than one measuring 2,200 c.c., and is therefore more likely to be digested easily. A flour from which large shapely loaves can be made probably contains more nitrogenous matter than a weak flour and is therefore more highly esteemed from the dietetic point of view. The effect of these considerations in the commercial world is to cause a demand for strong flours and wheats, and as ordinarily there is a larger supply of weak wheats than of strong, the latter realise a higher price than the former. It has therefore become important to ascertain the ultimate cause of strength from the chemist's point of view, also to ascertain whether the potential strength of any flour or wheat has been developed or utilised to maximum advantage. It has recently been stated or suggested that the quantity of gas given off in fermentation is either the direct cause of strength or is to be correlated with it. That proposition is untenable. A very large proportion of the gas evolved in panary fermentation is lost, either as a result of the mechanical handling of the dough or by gradual diffusion. The leak is not the same in the cases of all flours, and it was

shown at the last International Congress of Applied Chemistry (Humphries and Simpson) that the gas-retaining capacity of a set of flours indicated with substantial accuracy their relative strength. The gas-making capacity of any flour can be most materially modified by the baker or by the very latest developments of flour milling. The gas produced in the earliest stages of panary fermentation is lost so far as effective aeration of dough is concerned. All flours afford much gas in the early stages; and while some afford enough at all stages, very many do not. The total amount of gas evolved must be useless as an index of strength; for working purposes the gas evolved in the later stages of fermentation only may be used as an index. Even then any gas produced beyond what is necessary to overcome the leak and the relatively small quantity required for the inflation of the dough is wasted. It follows, therefore, that the problem before the miller or the baker is to make certain that any given flour should yield enough gas for practical working purposes whenever panary fermentation is to be taken into account.

It is obvious that the requirements of the yeast have to be considered; it must have a sufficiency of proper food. In other words, it must have sufficient sugar, soluble nitrogen and mineral food (phosphates). An addition of sugar sometimes increases the quantity of gas evolved in panary fermentation, sometimes diminishes it. My colleague Mr. A. G. Simpson (Humphries and Simpson—International Congress of Applied Chemistry, 1909) explained that point as follows: When a mixture of flour and water is made, a large proportion of the water goes into combination and this proportion increases as time passes. The food of the yeast is that part of the flour which goes into solution when water is added in dough-making. The quantity of sugar found in a flour before a dough is made with it is not a correct index of the quantity which will be formed by diastatic action when water is added. The quantity so produced will depend not only upon the enzymes concerned in diastatic action but also upon the physical state of their pabulum. It is known that yeast cannot thrive in a liquid containing sugar if the concentration of the sugar be high, and it has been ascertained that for optimum results the concentration should not exceed 15 per cent. From the foregoing considerations it will be gathered that during fermentation the proportion of water available to hold sugar in solution is diminishing, while a relatively large proportion of sugar is being produced as the result of diastatic action. It follows, therefore, that the concentration of sugar in the uncombined water may easily get beyond the proportion at which the optimum proportion of gas can be obtained. It follows also that, in certain cases, sugar can be added advantageously when an increased production of gas is desired; it can also be added advantageously in some cases when it is desirable to retard fermentation.

It may be asked whether the same principles apply in other cases of enzymic action. Can beneficial enzymic action be assisted or undesirable enzymic action retarded on such lines? Are there any reasons for believing that conditions favourable or unfavourable to alcoholic fermentation equally affect enzymic action? Has sugar a direct effect on the physical state of the gluten?

Mr. Whymper (in the Starch Section of the last International Congress of Applied Chemistry) showed by photo-micrographs and lantern slides that only a very small proportion of the starch particles is attacked by diastase. The small or smaller grains were shown to be unaffected by the diastase. Mr. Simpson has shown that, under certain conditions, a small proportion of flour converted into sugar a quantity of ungelatinised starch equal to 8 per cent. of the weight of the flour, but that under identical conditions the same quantity of the same flour converted a quantity equal to 400 per cent. of its own weight into sugar when gelatinised starch was used.

It seems, therefore, that the cellulose envelope of the starch cells is the impediment to the maximum effect of diastatic action.

These points have a direct bearing upon a point which arises in milling concerning fine *versus* coarse dressing—whether it is desirable to make a lively granular flour or a softer feeling flour consisting of much smaller particles. The latter should contain a much larger proportion of fissured cells than the former.

The author has found that flours made from wheat produced in very hot, dry climates, as a rule, yield relatively small quantities of gas in panary fermentation. The starch so produced by Nature becomes so stable and so resists disintegration that in fermenting flour made from such wheats under old conditions of milling proper diastatic action is not produced; by the skilful application of water, or by adding either malt extract or proper yeast foods, or by a combination of these methods, the miller can and should produce flour capable of making better and more nutritious bread.

Four years ago the author found that if an aqueous extract of bran be added to the water used in bread-making it has a marked effect in increasing the size of loaf from certain flours, the effect being substantially the same even if the extract be boiled. After analysing this extract and adding the various constituents found therein to many flours during the processes of bread-making, he found that when sugar was added it operated in ways already described; that absolute diastase or its equivalent in malt extract in many cases operated most beneficially; that nitrogen added in the form of more or less decomposed peptone, or better still in the form of ammonium phosphate, did a great amount of good in some cases; lastly, that the three phosphates forming almost exclusively the mineral matter of flour (phosphates of potash, magnesium and calcium) operated very beneficially in some cases. The phosphates did good frequently, even when the gas evolved in fermentation was reduced as the result of their use; the explanation of the benefit so obtained was not forthcoming until Professor T. B. Wood showed how dilute solutions of various acids, alkalis and salts had a very great influence on the physical characteristics of gluten.

It is desirable to ascertain whether these phosphates have a toughening effect on all flours or only in some cases; also whether it is desirable to obtain a proper balance of the three phosphates; in other words, whether it is the presence of any one in sufficient quantity which is essential or whether all that is necessary is to secure the presence of either or all in sufficient quantity.

If the soluble extract of the entire husk of wheat be used—that which the consumer would swallow in eating wholemeal bread—the effect on the bread is bad, but if we select from the whole set of constituents those which are desirable, we obtain good and sometimes very good results.

In view of the beneficial results obtained from treatment of some flours with these phosphates experiments in manuring wheat should be made with the phosphates of potash and magnesium instead of with the sulphates, so that it may be seen whether the plant can assimilate a larger quantity of these salts than it ordinarily does, and whether an increased quantity of the salts if found in wheat so manured has any effect on the quality of the flour and in particular on the quality of the gluten. The substitution of ammonium phosphate for sulphate of ammonia or nitrate of soda should also be tested.

As a result of panary fermentation the nitrogenous matter of flour originally insoluble in water becomes soluble to a very large extent indeed. It is desirable to ascertain whether this change should be helped or retarded and what is the optimum degree of such solubility.

Stability of Dough and Yield of Bread per Sack of Flour.—It seems at first sight that the yield of bread per sack of flour is likely to depend upon

the degree of stability the dough possesses, as if a dough be particularly stable the baker should be able to handle it satisfactorily, even if he add a larger proportion of water. This is only partially true; if two flours be carefully tested there comes a point at which the maximum slackness of dough is reached in each case, but even then one dough may be more stable than the other, may be tougher and more resilient—that is to say substantially better than the other. The consistency of the dough has to depend not upon the percentage of water it contains but upon its stability—that is to say upon the facility with which large masses of dough can be handled in the bakehouse. To get optimum results some flours should carry a relatively low and others a relatively high percentage of moisture, so that each shall produce the best results in bread. The baker is under no legal or moral obligation to the consumer to guarantee the water content of his goods, and if as a result of additional water, skilfully added, it is possible to produce better bread because it is better aerated or rendered more appetising, the addition of water needs no further justification.

It is obvious that the yield of bread per sack will depend very largely upon the quantity of water which any given flour will absorb and retain. The variable limit as to what water various flours will take will be determined by commercial practice and competition. There cannot be one uniform standard for the moisture which flours themselves should contain. The optimum figure will vary greatly according to many conditions and can only be determined satisfactorily by the miller and his skilled advisers.

These two points of quality in wheaten flour should therefore be regarded as essentially different one from the other, although in most cases they are closely correlated. In the author's opinion each country or district should produce those wheats which return the greatest yield of wheat fit for human food. In that way the grower gets in all probability the best financial return and the public interest is best served. It is well known that in certain districts better financial returns can be obtained by the grower if he produce wheats which are not highly esteemed in commercial circles.

---

8. *The Chemical Properties of Wheaten Flour.*

By E. Frankland Armstrong, *Ph.D.*, *D.Sc.*

Wheaten flour is composed of (1) starch, (2) proteins[1] of several kinds and small quantities of (3) fat, (4) sugar, (5) cellulose, (6) mineral matters. In addition, air-dry flour contains from 9 to 16 per cent. of (7) moisture.

Although starch is the predominating constituent, amounting to about 70 per cent., most attention has been directed to the proteins. When flour is made into a dough and the starch removed from this by agitation with water, a sticky, elastic mass of a light-brown colour remains; this is known as gluten and consists almost entirely of protein.

The definition of 'strength' now generally adopted (*see* Humphries, p. 775), based as it is on the character of the final product—the loaf—covers so many factors that it cannot be strictly correlated with chemical composition. It is, however, to be supposed that the determination of certain factors or groups of factors should enable some idea of the relative baking values of flours to be gained in the laboratory; experience has confirmed this view. The chemist requires the miller and the baker to define, as precisely as possible, the particular points they look for in a satisfactory wheat or flour. Mr. Humphries has rendered great service by his attempts to do this.

[1] The term protein is the modern equivalent of the older terms proteid or albuminoid.

In the following a brief review is given of the factors with which strength has been associated in the past. The explanation of 'strength' from the chemical point of view must be treated as a separate problem.

The preparation of sample loaves from a given flour still remains the most satisfactory test. It is essential that such loaves be prepared with scientific accuracy, under definitely standardised conditions, so that the only variable is the flour itself and possibly the amount of water used for doughing. Every mill desiring to produce uniform products is bound to have a laboratory for this purpose.

Gluten.

The oldest idea is that 'strength' is due to gluten; that in virtue of its elasticity this retains in the dough the gas produced during panary fermentation, and enables the dough to distend and keep up when baked. Flours containing most gluten should be the strongest. Experience has shown that a high gluten content is usually associated with strength, but in a great number of instances it has been found that of two flours, that with the higher gluten content behaves as the weaker when baked. Scientifically, therefore, gluten content cannot be considered an absolute measure of strength, although obviously connected with it.

Total Nitrogen.

Some of the proteins of flour are soluble in water and therefore are removed during the process of washing out the gluten. The determination of total nitrogen in a flour is less liable to the errors affecting the empirical methods of estimating gluten, but the results of such determinations are roughly parallel to the gluten content and afford no absolute measure of strength. Equally unsatisfactory is the determination of nitrogen in the dry gluten.

No doubt future work will involve the study of the forms in which nitrogen is present.

All measurements hitherto made indicate that strength depends on the *quality* rather than on the *quantity* of the proteins in flour. However, the protein content, when judging normal flours, is undoubtedly the best single measure of strength.

Quality of Gluten.

No satisfactory chemical data by which this can be gauged have been obtained. Measurements have been made, for example, of the power of expansion when a definite weight of gluten is heated in metallic cylinders to a definite temperature. Of greater significance is the water-holding capacity or *hydration ratio* as measured by the ratio of the wet gluten immediately after extraction under carefully standardised conditions to its weight after drying. The ratio is on the average about 3 : 1; that is, gluten carries about twice its weight of water. No generally accepted regularity has been demonstrated, but in gluten from strong flours the ratio is as low as 2.6, whilst in that from very weak flours the ratio is often above 3. As Mr. Hardy points out in the following paper, this ratio is to be associated with the mineral content of the flour.

Emphasis must be laid on the fact that the method of determining gluten by washing is purely empirical and requires careful standardisation before comparative results can be obtained. Measurements of gluten at the best are but a rough-and-ready guide to more exact determinations; they have the advantage that they can be made quickly without special apparatus.

Gliadin Ratio.

Crude gluten consists mainly of two proteins: *gliadin*, soluble in alcohol and *glutenin*, soluble in very dilute alkalis or acids. It has been suggested

that the ratio of gliadin to glutenin, or the ratio of gliadin to the total protein in the flour, influences the quality of gluten and affords a measure of strength. Girard and Fleurent suggested the proper proportion of gliadin to be 75 per cent. of the gluten. Snyder fixed the ideal ratio at 65 per cent., but experience has not supported these views; the gliadin ratio is erratic and apparently of little value for diagnostic purposes. A. D. Hall has adversely criticised the determination of the percentage of gliadin as an indication of strength; F. T. Shutt considers it to be more valuable, and suggests there is an indication of a relationship between the maturity of the grain and the gliadin content. The more fully ripened wheat contains the higher proportion of gliadin. The subject evidently demands further study.

Proteins of Flour.

As already indicated, wheat contains more than one protein. Gliadin and glutenin make up about 90 per cent. of the total protein matter of the seed; this in addition contains *leucosin*, a so-called albumen, which is freely soluble in water and coagulates when the solution is heated. In gluten the gliadin acts as the sticky binding substance, whilst the glutenin serves to fill up the network of gliadin threads.

These two proteins were thought at one time to have a common origin or to be derived from one another when flour is wetted. Osborne, who has studied the products of their complete hydrolysis, finds that gliadin differs sharply from glutenin in yielding no glycine and no lysine; it also gives nearly twice as much proline as glutenin.

Both gliadin and glutenin, which yield 37 and 23 per cent. of glutamic acid respectively, differ greatly from leucosin, which gives only 6 per cent. of this acid. They both give rise to considerable quantities of ammonia, whereas leucosin yields but little ammonia.

The substances mentioned as decomposition products of gliadin and glutenin all belong to the ‘ amino acids ’ which modern research has shown to make up the greater portion of the protein molecule.

T. B. Wood has carried out experiments which indicate that gliadin derived either from strong or weak wheats is the same in each case. Osborne's very careful researches all show that the proteins of wheat are of constant composition independent of their origin.

To sum up: whereas, broadly speaking, strength must be associated with the total quantity of gluten or nitrogen in a flour, yet it is the physical properties of gluten, rather than the amount, which determine the behaviour of the flour in bread-making.

Sugar.

The distention of the loaf is due to the gas formed during panary fermentation from sugar. The amount of sugar actually present in flour would not suffice to give the necessary volume of gas but it is supplemented by sugar produced from the starch of the flour. The formation of sugar is effected by the agency of a diastatic enzyme; it begins directly the flour is wetted and continues throughout fermentation until the loaf is baked. In general, therefore, the presence of more or less sugar in a flour is unimportant and the percentage shows no relationship with the volume of the loaf.

Diastatic Enzyme.

Obviously, there must not only be a plentiful supply of gas available to distend the loaf but also to maintain it fully distended until it is fixed in the oven. Flours which have relatively little diastatic enzyme will produce insufficient gas. A deficiency of diastase has been actually proved to occur in many flours tested, or at all events better loaves have been

obtained in such cases when malt extract or its equivalent has been added to the flour; generally flours contain an excess of diastatic enzyme. Gas escapes from the dough throughout the process of making a loaf; the amount escaping is apparently largest from those flours which contain gluten of lowest quality. The power of the dough to retain gas may be regarded as one of the separate factors involved in the conception of strength.

Wood has made comparative determinations of the amount of gas available for the distention of the dough by incubating flour with yeast and water and measuring the gas evolved, special attention being paid to the last stages of fermentation, since it is this gas which inflates the loaf at the moment it enters the oven. The attempt was made to correlate this factor with strength but this view has not been adopted, as it is not in agreement with practice. A further objection to these experiments is that they were made under conditions very different from those which prevail in actual bakehouse practice.

Another suggestion has been to correlate strength with the diastatic power of flour. This is impossible, firstly, because normal flours have more than enough diastase to produce the necessary sugar, and secondly, because the diastatic power of flour varies materially on keeping the flour sometimes increasing, at other times falling. The change in the diastatic power affords an explanation of the behaviour of some abnormal flours the baking strength of which very materially increased on keeping. Further, the diastatic power of flour increases considerably when sodium chloride or other salts are added to the dough.

Starch.

Hardly any attention has so far been paid to the properties of the starch of flour from the point of view of strength. Presumably, however, if the starch in one flour is more resistant to attack by diastase than that in another flour, sugar will not be formed so easily in the former and gas will not be generated so rapidly during fermentation.

Microscopic examination shows flour to consist of starch granules of three different sizes. The smallest granules which preponderate in amount are from 3 to 5 μ in diameter, the largest granules are about 30 to 35 μ and there are also granules of intermediate size. The microscopic examination of a large number of flours of different origin has shown that the large granules vary in number from 6 to $1\frac{1}{2}$ per cent. of the total number of granules. In other words, in one flour as much as 30 to 40 per cent. of the total weight of starch is in the form of large grains, whilst in another only 7 to 10 per cent. is in this condition.

Before a starch grain can be converted into sugar the cellular envelope has first to be destroyed. Obviously, when the envelope of the large granule is destroyed a much larger proportion of starch is rendered available than when the contents of a small granule are liberated.

Whymper has recently made a microscopic study of the changes occurring during the germination of wheat. He finds that the larger and more mature granules are the most readily attacked by the enzymes of the plantlet. Though there is no general relation between the size of starch granules of different origin and the ease with which they are attacked by diastase and other agents, it appears that the larger granules of any particular starch are affected sooner than the smaller granules.

The destruction of the cellular envelope of the granule is undoubtedly effected by an enzyme (cytase) about which very little is known. Julian Baker has suggested that poor flours lack a sufficient quantity of cytase, and in confirmation of this view showed that the addition of powdered malt, which contains such an enzyme, improves the size of the loaves obtained from such flours.

Mineral Matter.

The amount of ash in a flour seldom amounts to 0·5 per cent., more than one-half consisting of phosphates. There is undoubtedly some relationship between the mineral constituents and the gas-retaining power of gluten, though no complete analyses have as yet been published directly connecting strength with the composition of the ash. Wood, however, states that the soluble ash of Fife flour (milled from a strong English-grown wheat) shows a relatively high proportion of phosphate and magnesia and a low proportion of chloride, sulphate and lime; whereas the ash of a weak flour contained small proportions of phosphate and magnesia but much more chloride, sulphate and lime. The influence of small quantities of acids and salts on gluten is dealt with more fully by Mr. Hardy in the following paper.

Fat.

The amount of fat in flour varies from 1 to 1½ per cent., the higher value being a feature of flours from the Canadian North-West. The oil is present to the extent of about 15 per cent. of the wheat germ. It easily turns rancid and is characterised by a high iodine number (115).

Moisture.

The amount of moisture in commercial sacked flour depends largely on the atmospheric conditions at the time of milling and therefore on the climate of the country where it was milled.

Enzymes.

The diastase and cytase of flour have already been discussed. The proteoclasts have hardly been investigated. Attention was first drawn to them by Ford, who showed that some flours contain an active proteoclast which is very detrimental to the gas-retaining power of gluten. An erepsin has been identified in flour by Julian Baker. The enzymes in the yeast employed are however of the greatest importance to the practical baker.

BIBLIOGRAPHY.

Baker, J. L., and H. F. E. Hulton.—'Conditions affecting the Strength of Wheaten Flour' ('J. Soc. Chem. Ind.,' 1908, **27**, 368–376).

Baker, J. L., and H. F. E. Hulton.—'Behaviour of Wheaten Flour towards Bakers' and Brewers' Yeast' ('J. Soc. Chem. Ind.,' 1909, **28**, 778–781).

Brenchley, W. E.—'On the Strength and Development of the Grain of Wheat' ('Annals of Botany,' 1909, **89**, 117–139).

Ford, J. S., and J. M. Guthrie.—'The Amylolytic and Proteolytic Ferments of Wheaten Flour, and their relation to Baking Value' ('J. Soc. Chem. Ind.,' 1908, **27**, 389–393).

Girard et Fleurent.—'Le Froment et sa Monture' (Paris, 1903).

Hall, A. D.—'The Question of Quality in Wheat' ('Journal of Board of Agriculture,' 1904, **11**, 321).

Hall, A. D.—'Recent Developments in Agricultural Science' ('Report Brit. Assoc.,' South Africa, 1905).

Home Grown Wheat Committee of the National Association of British and Irish Millers, Reports of the, for 1905, 1906.

Humphries, A. E.—'Causes of the Quality Strength in Wheat Flour' ('Report Brit. Assoc.,' Leicester, 1907). See also 'The Miller,' 1907, p. 414 (September 2).

Humphries, A. E., and R. H. Biffen.—'The Improvement of English Wheat.' ('J. Agric. Sci.,' 1906, **2**, 1–16).

Osborne, T. B., and C. G. Voorhees.—'The Proteins of the Wheat Kernel' ('Amer. Chem. J.,' 1893, **15**, 392–471; 1894, **16**, 524–535).

Osborne, T. B., and I. F. Harris.—'The Chemistry of the Protein Bodies of the Wheat Kernel' ('Amer. J. Physiol.,' 1905, **13**, 35-44; 1906, **17**, 223-230, 231–265).

Saunders, C. E., and F. T. Shutt.—'Milling and Chemical Values of Grades of Wheat in Manitoba.' ('Bulletin Canadian Experimental Farm,' No. 50, 1904; No. 60, 1907).

Saunders, C. E., and F. T. Shutt.—'Quality in Wheat' (Bulletin, No. 57, 1907).

Shutt, F. T.—'The Relation of Composition of Flour to Bread Value' ('Int. Congress of Applied Chemistry,' London, 1909).

Shutt, F. T.—'The Influence of Environment on the Composition of Wheat ('J. Soc. Chem. Ind.,' 1909, **28**, 336-338).

Snyder.—('Minnesota Expt. Station Bulletin,' 1904).

Whymper, R.—'Microscopic Study of Changes occurring in Starch Granules during Germination of Wheat' ('Int. Congress of Applied Chemistry,' London, 1909).

Wood, T. B.—'The Chemistry of Strength of Wheat Flour' ('J. Agric. Sci.,' 1907, **2**, 139–161; 267–277).

Wood, T. B., and Hardy, W. B.—'Electrolytes and Colloids; the Physical State of Gluten' ('Proc. Roy. Soc.' 1909, **1381**, 38–43).

---

9. *An Analysis of the Factors contributing to Strength in Wheaten Flour. By* W. B. Hardy, *F.R.S.*

Reduced to the simplest terms the physical properties of dough depend upon the protein complex gluten, starch grains and water. The greater the water-absorbing power of the gluten, that is the greater its water content, the less will be its tenacity and, within limit, the greater its ductility.

Colloid bodies such as moist gluten have a sponge structure, and when solid particles are present the bars of the sponge-work may be seen under the microscope to spring from them. Thus solid particles may enter intimately into the framework, and by their size and number modify the thickness and length of the bars and the size of the interspaces. Rubber loaded with solid particles has elastic properties widely different from those of rubber free from particles, and moist gluten loaded with starch grains differs from gluten washed approximately free from them. It is less like elastic, more like putty, in its mechanical properties—the solid grains of starch act as though they enormously increased the internal friction.

There has, so far as I know, been no exact work upon the influence of the size and number of the starch grains upon the mechanical properties of dough; in the absence of such information it is idle to pursue the point further. This may however be said; judging by what is known of the influence of embedded small particles in other cases the power of the dough to retain its shape may be due in some cases primarily to the nature and number of the starch grains. Whatever the influence of the starch grains may be, they operate as passive agents; the active mechanical properties of dough, its tenacity and ductility, are due to the protein complex gluten. This is the labile elastic cement of the structure.

Now gluten, even though it be prepared from the best Fife flour, *has of itself neither ductility nor tenacity.* In presence of ordinary distilled water it partly dissolves, the residue—the larger portion—forming a semi-fluid sediment destitute of tenacity. Why? Because tenacity and ductility are properties impressed on gluten by something else—namely by salts, by electrolytes, that is, which may be organic and may therefore be unrepresented in an ash analysis.

This being the case it is obvious that any attempt to correlate strength with the physical properties of gluten washed out in the ordinary way must end in failure, since the properties of washed gluten depend upon the electrolytes which happen to be left in after the washing is concluded.

Electrolytes—that is to say salts, acids and alkalis—intervene in two absolutely distinct ways. They control the physical properties of the gluten in the dough, and they must also profoundly modify the temperature relations and the rapidity of the change undergone by the gluten and other constituents of the dough in the process of baking—a change which, so far as the proteins are concerned, is, broadly speaking, a lowering of solubility. We know something of the way in which they act on gluten in the dough, but of the more complicated action during temperature changes we know nothing; it is possible that the same electrolyte may increase the mechanical stability of the loaf in the dough and yet diminish it in the oven.

Let us turn to the action of electrolytes upon moist gluten, that is, upon gluten as it exists in dough.

Gluten prepared from wheat by washing the flour in many changes of water is a stringy ductile body capable of retaining bubbles of gas. When it is placed in dilute acid or alkali this property vanishes. As little as 1 part of sulphuric or hydrochloric acid in 20,000, or 1 in 5,000 of acetic or lactic acid, will disperse the gluten in fine particles. There is not only the loss of actual cohesion; the gluten particles are so changed that they actually repel one another and a non-settling milky suspension is produced. In order to restore cohesion it is merely necessary either to neutralise the acid or to add any salt such as common table salt.

Any salt confers cohesion upon gluten; any acid or alkali when sufficiently dilute lessens or destroys it. Gluten itself seems to be purely passive.

The removal of salts by washing gluten with distilled water will lower the forces which make for cohesion, so that less and less acid is needed to neutralise them; a point may be reached where apparently any concentration of acid, no matter how low, is sufficient. When gluten is thoroughly extracted with distilled water it loses cohesion and disperses as a cloud, not owing to the action of the water but because of the faint acidity due to the carbonic acid dissolved from the air. This can be proved in many ways, most directly perhaps by the fact that careful neutralisation of the carbonic acid will restore cohesion. A brief but more detailed consideration of the action of acids, alkalis and salts is needed to make these points clear.

Action of Acids and Alkalis.—Acids and alkalis produce the same physical effects, but the latter also induce hydrolytic decomposition of the gluten. The effect of acids is therefore more easily followed, and for simplicity I propose to confine my remarks to them.

Gluten prepared in the ordinary way and immersed in distilled water retains its cohesion unless measures be taken to wash out the salt which it contains. In N/1000 of any strong acid cohesion breaks down and the change is more rapid as the concentration of acid is *increased* up to about N/30. Further increase in concentration slows the rate of disintegration, until at N/12 for hydrochloric acid, N/25 for sulphuric acid and 1·75 N for phosphoric acid the gluten again becomes permanently *coherent* and more tenacious and less ductile than in its original state. Weak acids, such as oxalic, acetic, lactic, citric and tartaric acids, produce disintegration in dilute solution but fail to maintain cohesion even at very high concentration.

When salt is added to gluten which has lost cohesion owing to the action of acid this property is restored, but the concentration of salt needed to undo or prevent the action of the acid varies with the concentration of the acid in a remarkable and characteristic manner. The relations can be best explained by reference to the curve. The ordinates are concentration of

sodium chloride, the abscissæ concentration of sulphuric acid, in both cases expressed in gram equivalents per 1,000 litres. The curve gives the concentration of salt and acid needed just to preserve cohesion. It will be seen that as the concentration of acid is increasing, the concentration of salt needed to maintain cohesion rises to a maximum and thence falls until a point is reached where the acid alone is sufficient. The curve encloses an area of no cohesion, while outside it is a region in which acid and salt maintain cohesion.

Neither of these areas represents uniform states; as is characteristic of colloidal matter, they are areas of continuous changes. The curve which limits them is merely an arbitrary line which marks the place at which cohesion is so far reduced that it no longer suffices to maintain shape against the extraneous force of gravity. Any line, starting within the area of no cohesion and passing through it to the area of cohesion, traverses a system which is continuously changing—namely, a colloidal solution containing exceedingly fine particles of gluten which become continuously coarser until finally, at or near the intersection of the curve, they run together into

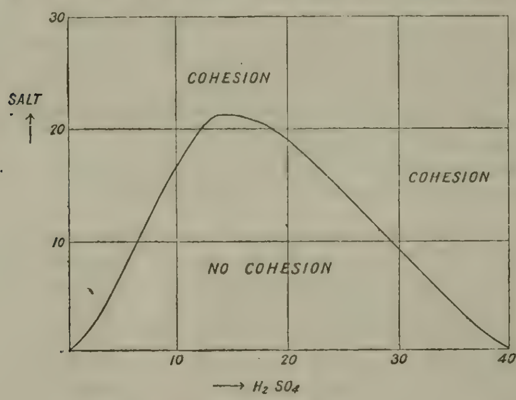


FIG. 1.

a coherent mass of gluten. Beyond the curve the line, if it be inclined upwards, follows a system in which still further separation of water and gluten is taking place, the two becoming less and less miscible—the water-holding power of the protein less and less, its tenacity growing, its ductility diminishing.

Electrolytes therefore do more than confer on gluten its mechanical properties; they determine also its power of holding water. They also determine the water-holding power of any other colloid matter present in the dough.

Acids and alkalis destroy cohesion and disperse the particles of gluten just as they produce and stabilise non-settling suspensions in many types of colloidal solution—namely, by the development of a difference of electric potential between the particles and the water. The curve which connects the potential difference with the concentration of acid has the same form as the curve given in fig. 1.

The foregoing analysis of the factors which control the physical properties of gluten in moist dough lead us to a brief analysis of the source of 'strength' in flour. It must be borne in mind that loaf-making includes two distinct operations, the making and incubation of the dough and the fixa-

tion of the incubated dough by heat. Every factor which contributes to the rising of the dough—that is, to the size of the loaf—and to the power of the dough to preserve its shape (saving only the vital activities of the yeast plants) intervenes also in the fixation of the dough, where it may undo what it has already done. Successful incubation depends upon: (1) The suitability of the dough for the active growth and production of carbonic acid by the yeast plant, which again depends upon the concentration of sugar, the intrinsic diastatic power of the dough and the concentration and nature of the electrolytes. (2) The physical character of the dough, which depends upon the size, shape and number of starch grains, the nature and concentration of the electrolytes, since these determine the physical properties of colloids present, notably the gluten. The electrolytes will also direct those molecular rearrangements which occur during the baking process, and which give fixity and stability to the entire structure.

---

10. *Chemical Work on Canadian Wheat and Flour. By* FRANK T. SHUTT, *M.A., F.I.C., Chemist, Dominion Experimental Farms.*

A quarter of a century ago those who were taking cognisance of Canadian development and progress had begun to realise that Canada was destined to become one of the largest wheat-producing countries in the world. The North-West had been, so to speak, discovered, and, at least in parts, its suitability for the production of wheat of the very finest quality established. Since that time the area sown to wheat in the North-Western Provinces has annually increased, of late years at a phenomenal rate. Last season (1908) the western plains yielded in round numbers 106,000,000 bushels from, approximately, 6,000,000 acres; in 1902, only six years ago, the acreage in wheat was less than half that sown last season, with a yield of 67,000,000 bushels. The estimate for the present year (1909) for the three western provinces, Manitoba, Saskatchewan, and Alberta, is 7,000,000 acres in wheat—a million acres increase a year. And that the possibilities for the further expansion are by no means exhausted will be evident from the fact that as yet but five per cent. or thereabouts of the tillable land is under crop.

It was the thought, therefore, that wheat was destined to become, in Canada, a staple crop of the largest magnitude that determined us, almost immediately on the establishment of the experimental farm system, some twenty-two years ago, to devote special attention in the field and laboratory to the solution of problems in connection with this cereal. In this Paper it will only be possible to mention some of the more important investigations undertaken by the Chemical Division, presenting very briefly the data obtained and the conclusions reached. More detailed consideration of these various questions will naturally be found in the annual reports and bulletins issued from the Chemical Division of the Experimental Farms, and to which numerous references will necessarily be made.

Red Fife and Imported Wheats.

One of the earlier investigations had for its object the introduction of a wheat equal in quality to the well-known and highly esteemed North-Western Red Fife, which might ripen earlier and thus escape injury to which that variety is occasionally exposed from autumnal frosts. To this end, in 1887, a number of wheats were imported from India, Northern Russia and other European countries, prominent among which were the varieties Ladoga, Saxonka, Kubanka, and Onega. These, as well as varieties obtained from the North-Western States—Wellman's Fife and

Bluestem—were submitted at the outset to chemical and physical examination to determine their relative values as compared with Red Fife, and to ascertain, after growth in various parts of Canada, the effect of environment, soil, climate, &c., upon their composition.[1]

Among the more prominent deductions made from this work were the following:—

1. That the percentage of protein of the Canadian-grown Russian wheats was very similar in amount to that of Red Fife. The averages were as follows: Ladoga, 14·31 per cent.; Saxonka, 13·91 per cent.; Kubanka, 13·77 per cent.; and Red Fife, 14·00 per cent.

2. That the Manitoba-grown Red Fife was fully equal, and indeed somewhat superior in protein, to the best-grown varieties of Minnesota. The samples examined furnished the following averages: Wellman's Fife, 13·68 per cent.; Bluestem, 11·75 per cent.; Red Fife, 14·00 per cent.

3. That growth in the Canadian North-West had, in the majority of instances, markedly increased the gluten content. Thus, imported Ladoga contained 12·75 per cent. protein, while the average of eight samples of grain grown in the North-West from this seed was 14·57 per cent., a significant illustration of the influence of environment on the composition of wheat.

In 1893, when Ladoga had been successfully grown for several years in certain districts of the North-West, a further and more exhaustive study of its flour was made, supplemented by baking trials on a large scale.[2] We found that, compared with Red Fife, Ladoga yielded a gluten of inferior quality; it was less elastic, more sticky, and yellower. Though occasionally, with special manipulation, a well-risen and fairly white bread was obtained, in the larger number of trials, and when the baking methods were not specially modified, the bread was somewhat flat, heavy, and yellowish. Our experiments indicated further that, weight for weight, Ladoga flour yielded a larger weight of bread than that of Red Fife.

Composition of Canadian and Foreign Wheats.

As a professional juror at the World's Columbian Exposition, held in Chicago, 1893, the writer co-operated in the analysis of the cereals submitted for award. In this series there were 166 samples of wheat, forty-nine of which were from Canada. The analytical data, which have been published *in extenso*,[3] furnished evidence of the high nutritive qualities of Canadian cereals in general, demonstrating more particularly the superiority of Red Fife and White Fife wheats as grown in Manitoba and the North-West.

Cross-breds from Red Fife and Ladoga.

Following up this line of investigation, we undertook, in 1899, a comparative study of Red Fife, Preston, Stanley, and Percy wheats as grown in Manitoba, the three latter varieties being cross-breds originated at the Central Experimental Farm from Red Fife and Ladoga.[4]

The most noticeable feature was the great similarity in composition of the four members of the series. Judged by chemical standards accepted at that time, all were exceptionally good, comparing most favourably as regards protein content with average market samples of the best wheats of the world. Of the cross-breds, Preston only falls behind in protein, while both Percy and Stanley showed slightly higher percentages than

[1] Bulletin No. 4. Ladoga, Red Fife, and other varieties of Wheat. March 1889.

[2] Bulletin No. 18. Ladoga Wheat. February 1893.

[3] *Report of the Chemist*, Central Experimental Farm, 1895. Bulletin No. 45, Division of Chemistry, U.S. Department of Agriculture, Washington, D.C.

[4] *Report of the Chemist*, Central Experimental Farm, 1900.

Red Fife. The figures were as follows: Red Fife, 12·84 per cent.; Preston, 11·86 per cent.; Stanley, 13·16 per cent.; Percy, 13·67 per cent.

The Grades of Wheat.

The installation in 1904 by the Cerealist of an experimental roller mill and baking oven permitted us from that date on to enlarge the scope of our work with wheats, making it possible to submit to examination the flours from the wheats under inquiry, and to attempt correlation of the chemical and physical data with the results of actual baking trials.

It was thought that some light might be thrown on the question of what constitutes quality in wheat by a closer chemical study of the various commercial grades and the flours that might be obtained from them. The product of the western wheat fields is annually inspected and graded by a Government official, and it was considered of interest to ascertain how far the composition of the wheats, as revealed by chemistry, might agree with the official grading. With these objects in view, samples representing the grades from the crops of 1904 and 1907 (Manitoba Inspection Division), with their respective flours, were submitted to analysis.

As might be expected from the fact that at least 90 per cent. of the wheat of these grades is Red Fife, the differences in composition are rather those of degree than of kind. It would appear, therefore, as regards the western wheat, that it is the relative yield of first-class flour (as determined largely by colour) that furnishes the chief basis in the grading rather than any essential differences in the relative strengths of the wheats, though the percentage of piebald or starchy kernels is also taken into account. The 'straight' flours from all the higher grades were found to be characterised by a high protein content and an excellent baking value; there seems little doubt but that when examining flours from the same variety the protein content may be taken as a sure index of strength. In flours from normally ripened grain there evidently exists a distinct relationship between protein, gliadin, and dry gluten (as determined mechanically); immaturity—as resulting from the effect of early frosts, &c.—disturbs this relationship, the less fully ripened containing the smaller proportion of gliadin.

These are some of the more important deductions made from the work on these wheats and flours; the detailed results have appeared in bulletin form.[1]

The Relationship between Composition and Bread-making Value.

During 1906 and 1907 two series of flours from wheats specially selected as representative of spring, winter, and durum varieties (including many cross-breds originated at the Central Experimental Farm) were examined with a view of determining, as far as might be possible, the relationship, if any, between composition and bread-making value, and further, if the contentions of Professor T. B. Wood, of the University of Cambridge, recently put forward regarding the factors that determine strength in flours, would receive support.[2] In this work, as in former investigations in which flours were examined, we had the co-operation of the Cerealist, who conducted all the milling and baking tests. The conclusions arrived at may be briefly given as follows:—

[1] The Grades of Wheat, 1904, Bulletin No. 50, Expl. Farm Series. The Grades of Wheat, 1907, Bulletin No. 60, Expl. Farm Series.

[2] *Journal of Agricultural Science*, vol. ii. part i.

1. That while, as already noted, the percentages of gliadin and dry gluten increase and decrease with that of the protein, the ratio between these determinations is neither constant nor definite.[1]

2. That there is a well-marked relationship between the 'baking strength'[2] of a flour and its percentages of protein, gliadin, and dry gluten. The data from both series of flours clearly indicate this relationship, though it was not always possible to establish a definite ratio between the chemical and baking results.[3]

3. That, while the protein content is undoubtedly the best single measure of strength when judging normally ripened wheats of the same variety, the character of the gluten must be especially taken into consideration when discriminating between wheats of different varieties. In flours of high bread-making values the gluten is resilient, elastic, firm and cohesive; in poor flours it may be flabby, non-resilient, soft, or sticky.

4. That the view held by many chemists that the gliadin ratio or 'number' is of importance as an index of strength received no confirmation from the analysis of Canadian flours. The generally accepted statement that from 55 to 65 per cent. of the protein should exist in the form of gliadin is undoubtedly incorrect; the larger number of the strongest flours examined possessed a gliadin number below fifty. The gliadin number, though holding with the other nitrogenous data in parts of the series, is on the whole erratic, and apparently of very little value for diagnostic purposes. The percentage of gliadin is, according to our evidence, decidedly more valuable.[4]

5. That we failed to obtain any evidence confirmatory of the view held by Mr. Wood: that the amount of nitrogen and ash free extract controlled the volume of loaf. If the size of the loaf is determined by the volume of gas evolved in the bread-making process, then this volume is dependent on the enzymic action (which may affect the protein as well as the carbohydrates) rather than on the amount of sugar present in the flour.[5] We have not observed any relationship between the percentages of sugar, as actually determined, and the volume of loaf.

6. That, while certain of our data seemed to indicate an agreement between the ratio to total nitrogen of soluble salts and shape of loaf—as held by Professor Wood—they did not permit of any direct correlation.[6]

The Effect of Dampness on the Quality of Wheat.

It sometimes happens in the wheat fields of North-Western Canada that, owing to inclement weather following the cutting of the grain, wheat becomes damp while in the stook, and may remain so for some weeks before it is threshed. As such wheat is accounted of a lower commercial grade by reason of the duller and paler appearance of the grain, because also of the common impression that the moisture in the grain has injuriously affected the gluten and thus impaired the resultant flour for bread-making

[1] Quality in Wheat, Bulletin No. 57, Exp. Farm Series, pp. 44, 49. *Report of the Chemist*, Exp. Farms, 1908-09, p. 146.

[2] In determining the 'baking strength' of a flour, values have been assigned to water added, water retained, volume, shape and texture of loaf and form of crust (Bulletin No. 57, Exp. Farm Series, p. 18).

[3] Bulletin No. 57, pp. 41, 45, 50. *Report of the Chemist*, Exp. Farm Series, 1908-09, p. 146.

[4] Quality in Wheat, Bulletin No. 57, pp. 41, 42. *Report of the Chemist*, Exp. Farms, 1908-09, p. 146.

[5] Quality in Wheat, Bulletin No. 57, pp. 43, 47, 48.

[6] The Grades of Wheat, Bulletin 60, p. 19. *Report of the Chemist*, Exp. Farms, 1908-09, p. 147.

purposes, it became a question of considerable importance to ascertain, by chemical and baking tests, how far this contention might be correct. Wheat that has been damp through exposure and subsequently dried is known commercially as 'tough.' Three samples of such wheat from the crop of 1907, which had been dried at the elevator, were submitted to analysis. All were found practically normal as regards moisture, and gave glutens of excellent quality. We concluded from a general survey of the analytical results that these wheats, from which about 5 per cent. moisture had been driven off at the elevators, had not appreciably suffered in quality.[1]

Further prosecution of this inquiry was made possible through the co-operation of Dr. Charles E. Saunders, the Cerealist, who had instituted a series of experiments to learn what deterioration might take place in bread-making value when wheat was kept more or less damp for a longer or shorter period before being milled. The wheat under experiment remained moist at temperatures ranging from 40° F. to 58° F. for a period of twenty-seven days, samples being taken for analysis at various intervals (five minutes, ten, twenty, and twenty-seven days), spread in thin layers to dry and then milled. In the sample that had been kept twenty days mustiness was noticed, and in that which had been damp for twenty-seven days the mustiness was more pronounced, and sprouting had commenced. The analysis of the resulting flours was of the most comprehensive character. A detailed study of the results indicates that wheat may contain an excessive amount of moisture for some considerable time without its composition being very materially affected. It was evident, however, that there had been a slight falling off in the percentage of dry gluten and a deterioration in quality in those wheats in which the mustiness was marked and sprouting had begun.[2]

Influence of Storage on Wheat and Flour.

It is generally conceded that flour improves as to colour and strength with age. To discover such changes in composition as might explain this improvement, a considerable amount of chemical work has been done on a series of wheats and flours stored under ordinary conditions by the Cerealist for the purpose of determining the influence of age on bread-making value. The storage period was sixteen months, three of the series being kept both as grain and flour, and four as grain only.

The Cerealist found that 'when the material is kept over in the form of flour there is a more rapid improvement in colour and in strength than when it is kept as wheat. In every instance there was a gain in water-absorbing power, and as a rule this gain was considerable. There was also invariably an improvement in the shape of the loaf.' The chemical data indicated a slight increase in the protein content, this increase being more marked in samples which had been kept over as flour. The probable explanation of these phenomena is that the carbo-hydrates are being continually oxidised, the rate of oxidation being determined by the area of surface exposed.

A slight improvement in the physical characters of the gluten from the stored wheats and flours was remarked, the improvement being more noticeable in the weaker members of the series.

A tendency towards an increase in gliadin was observed, showing a certain amount of parallelism between protein content and gliadin.[3]

[1] *Report of the Chemist*, Exp. Farms, 1908-09, pp. 148, 149.
[2] *Ibid.*, pp. 145, 146.
[3] *Ibid.*, pp. 149, 150.

The Influence of Environment on the Composition of Wheat.

While it has been held that the composition of the crop is determined largely by that of the parent seed—in other words that heredity is a potent, possibly in some cases the dominant, factor in influencing the character of the seed—it seems nevertheless true also that environment has a most marked effect on the grain. The term environment here is naturally used in its widest sense, and would include the influences exerted by climatic conditions, nature and culture of soil, &c.

It has been a matter of common observation that wheat grown on newly cleared scrub-land in certain districts of the North-West is more or less 'soft' or starchy in character. The seed sown may be No. 1 Hard or No. 1 Northern — hard, semi-translucent, and glutinous — and the product on such soils will, as a rule, contain a proportion of kernels with whitish, opaque spots—piebald wheat—indicating clearly a deterioration in quality from a commercial point of view. With cultivation of the soil this tendency to produce soft, starchy wheat apparently disappears, the character of the wheat generally improving, so that after a number of years the quality of the wheat grown may be greatly superior, as measured by protein content, to that which is at first produced. Though the change is usually gradual and in the same direction, it has been noticed that the quality of the wheat on such land is markedly influenced by the character of the season, so that while in some years there may be but little difference between the crops from the older and the newer land (seed of the same description being sown on both), in other years the difference may be so great that their common parentage is not at all apparent.

This change from a hard, semi-translucent kernel to one that is soft or piebald is a change, as already indicated, not only in external and physical characters but in chemical composition; it is a falling off in commercial value marked by a decrease in the protein (gluten) content. Its extent can therefore be accurately traced by chemical means.

The Dauphin district (North-Eastern Manitoba) is one of those in which there is a considerable area of this scrub-land—*i.e.* land covered with small trees, shrubs, &c., and generally characterised by a high percentage of vegetable matter. As a rule, the district is favoured with an abundance of rainfall. Its wheat has been very largely piebald in character, though settlers claim it is improving in quality with the working of the soil. In 1905 we obtained from Valley River, in this district, three samples of wheat and submitted them to analysis:—

A.	Wheat used as seed	11·11 per cent. protein
B.	Wheat grown as first crop after 'breaking' .	9·93 ,, ,,
C.	Wheat grown on soil cultivated 9 years . .	12·62 ,, ,,

First, we have in these results an illustration of the extent to which environment may affect the composition of wheat in one season. Secondly, it is to be noticed that the wheat from the newly cleared land (B) is decidedly less glutinous (softer, starchier) than the grain from the older soil (C). The wheats differed considerably in appearance. The seed wheat was a fairly good sample, grading No. 1 Northern; the product from this on the new land was decidedly soft, with many opaque starchy kernels; that from the older soil was somewhat superior to the parent seed.

To ascertain, if possible, the factors that determined this modification, the softer grain (B) was sown the following season on areas of newly cleared and old land on the same farm. In addition to the analysis of the wheats harvested, soil-moisture determinations were made from time

to time throughout the growing season, and samples representative of the soil of the areas under experiment chemically examined:—

	Wheat used as seed (B)	9·93 per cent. protein	
D.	Wheat grown as first crop after 'breaking'	10·01 ,,	,,
E.	Wheat grown on soil cultivated 10 years	13·52 ,,	,,

Wheats (B) and (D) would be termed piebald or soft, and are very similar in appearance. Wheat (E) shows no starchy grains, the kernels being hard and translucent, typical of the highest grades. The difference in protein content between (B) and (D) is insignificant, but between these wheats and (E) it is very great—3·5 per cent.

The moisture content of the soils of the two areas was found to be as follows:—

——	May 5	May 15	May 29	June 22	July 13	Aug. 2	Aug. 24
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Newly cleared land	32·96	36·49	33 45	30·49	35·23	30·37	32·84
Cultivated land	22·45	23·39	23·39	21·70	21·24	13·24	18·28

These data are highly significant. The newly cleared soil which produced the softer wheat was throughout the growing season more moist; its percentages of water ranged from 9 to 14 higher than those of the soil giving the harder grain. And it is to be noted that there was no drying out in the newly cleared soil as the season advanced.

The soils on analysis were found to have the following compositions:—

——	Newly cleared Soil	Soil 10 years under Cultivation.
	Per cent.	Per cent.
Moisture	2·98	2·06
Organic and volatile matter	20·90	12·84
Insoluble residue (sand, clay, &c.)	51·74	65·07
Oxide of iron and alumina	5·50	10·52
Lime	10·25	3·47
Magnesia	2·44	1·63
Potash	0·14	0·19
Phosphoric acid	0·15	0·13
Soluble silica	0·02	0·02
Carbonic acid, &c. (undetermined)	5·88	4·07
	100·00	100·00
Nitrogen in organic matter	0·642	0·371
Available constituents:		
Phosphoric acid	0·0067	0·0067
Potash	0·0166	0·0069
Lime	1·306	0·93

The characteristic feature of these soils is their richness in vegetable matter and nitrogen; it will be noticed that the percentages of these constituents are very considerably higher in the newly cleared soil. This larger proportion of humus is probably the true explanation of the higher moisture content of the newly cleared soil, since humus enhances the absorptive and retentive capacity of a soil.

In potash and phosphoric acid these soils present no striking differences, though the newer soil is much the richer in lime. The data, apart from

the relation of humus to moisture content, throw no light upon our problem.[1] It is interesting, however, to observe that the soil with the higher percentage of nitrogen produced the starchier wheat. From these results we were led to believe that the explanation for the difference in composition of the wheats is to be found in the widely different moisture content of the soils throughout the growing season, the larger amount of moisture prolonging the vegetative processes of the plant and delaying the maturation of its grain. This apparently allows the further deposition of starch, or rather of less nitrogenous matter, resulting in a more or less soft kernel.[2]

If these conclusions are correct, then it might be conjectured that wheat grown under irrigation in a semi-arid district would be more or less glutinous according to the amount of water supplied during the development period. To obtain information concerning this matter, areas irrigated and non-irrigated were sown in 1908 on the Experimental Farm, Lethbridge, Southern Alberta, with Red Fife and Kharkov wheats. This district is usually one of sparse precipitation, and one, consequently, where the methods of the so-called 'dry' farming must be practised in parts where there is no provision for irrigation. As a rule, irrigation is necessary to obtain the best yields. The season during the earlier months was unusually wet, and consequently not favourable to the experiment in hand, only one irrigation, July 16, being found necessary; nevertheless, as the following data clearly show, the irrigated soil, with its higher water content, produced the more starchy wheat.

Red Fife—original seed from Brandon, Man.	15·95	per cent. protein
Red Fife—grown on irrigated land	13·70	,, ,,
Red Fife—grown on non-irrigated land	16·37	,, ,,
Kharkov—grown on irrigated land	12·11	,, ,,
Kharkov—grown on non-irrigated land	13·12	,, ,,

In the case of Red Fife, the wheat grown on the non-irrigated and, as we shall see, drier soil contained 2·5 per cent. more protein than that from the irrigated area. Similarly with the Kharkov, there is a difference of 1 per cent. protein in favour of the non-irrigated wheat.

The soil-moisture determinations made at intervals throughout the season are as follows:—

——	Irrigated	Non-irrigated
	Per cent.	Per cent.
May 14, 1908	16·56	15·61
July 15, 1908	8·78	8·11
August 17, 1908	10·37	6·38

From the beginning of the season until the middle of July, during which time there had been no irrigation, the soils on both plots were very similar in water content, the figures showing a steady decline. Subsequent to that date the percentage of water continued to fall off in the non-irrigated plot, while in the adjacent irrigated area, as might be expected, it increased.

In these results we again have satisfactory evidence that the composition of wheat is markedly influenced by the amount of soil moisture present during the development of the kernel.

[1] The analysis of the wheats from the fertiliser plots of the Experimental Farms confirms the view that manuring has but little influence on the composition of the grain.

[2] *Report of the Chemist*, Exp. Farms, 1907-08, pp. 135-9.

To sum up, climatic conditions influence the quality of the wheat through the vegetative processes by shortening or lengthening the time which elapses between the formation of the kernel and its maturity—the shorter the period, the higher the protein content within certain limits. High temperatures, long days, and absence of excessive moisture during the later weeks of development, we have evidence, hasten the maturation of the grain and increase its percentage of gluten. These are the conditions that prevail in the North-Western wheat areas in those seasons which give the largest proportion of first-quality wheat, and we may therefore argue that in them we have an asset fully equal in importance towards the production of the finest grain to that which we possess in our fertile prairie soils.

---

11. *A Comparison of the Baking Qualities of the Flour from some of the Grades of Wheat produced in the Western Provinces of Canada. By* Professor R. HARCOURT.

The object of the investigation was to learn something about the relative bread-making value of leading grades of wheat now produced in Canada. The work included a study of three grades of spring wheat, *i.e.* Nos. I., II. and III. Northern, and of the most important grades of winter wheat grown in Alberta—Nos. I., II. and III. Alberta Red and Nos. I., II. and III. White winter wheat. The spring wheat is the most important, as it forms a very large proportion of the wheat exported, whilst only a comparatively small amount of the Alberta Red and very little of the Alberta White has been exported. The chief variety among the spring wheats is the well-known Red Fife. The Alberta Red is in reality the Turkey Red, originally of Russia, brought into Alberta from the State of Kansas, where it is known as Kansas wheat or Kansas Red; Dawson's Golden Chaff forms the greater part of the Alberta White winter wheat.

It is a well-recognised fact that the conditions included in the term environment cause very marked differences in the quality of the same variety of wheat. Thus climate—including under this term the variations due to season and the condition of the soil—has a very marked influence on the quality of the wheat produced; consequently the milling qualities of the wheat and the baking properties of the flour produced from it are bound to vary from year to year. No attempt has been made in the work herein reported to study the influence of environment, the object having been to compare the quality of the various grades of wheat as they appear on the market. It is true that a miller may purchase wheat of a certain grade in one district that may be superior to that grown in another; but the great bulk of the wheat passes through the large elevators, in which wheat from many districts, grown under a great variety of conditions, is mixed together, so that the characteristics peculiar to localities are lost in the general mixture.

One set of samples, Nos. I., II. and III. Northern, were received direct from Mr. David Horn, Chief Grain Inspector; they were taken from his mixed samples, but probably these were not gathered from an area wide enough to exclude all the influences of environment. Another set of Nos. I., II. and III. Northern was secured from the elevator at Goderich, Ontario; the samples represent these grades as they actually reach the miller in the older provinces or in Great Britain. The samples of Alberta Red and Alberta White were sent from the Grain Inspector's office at Calgary, Alberta.

The following table gives data which in a general way indicate the quality of the wheat:—

TABLE I.—*Comparative Weights of Wheat, Percentage Yield of Flour and Protein Content of Wheat.*

Grade of Wheat	Weight of 100 Kernels. Grams.	Weight per measured Bushel	Per cent. of Protein	Per cent. of Flour [1]
SPRING WHEAT.				
Winnipeg sample:				
No. I. Northern. .	2·89	62·5	11·66	57·6
No. II. " . .	3·02	62·25	11·33	55·8
No. III. " . .	3·10	61·0	11·36	50·0
Cargo lots:				
No. I. Northern. .	2·70	63·5	11·48	55·0
No. II. " . .	2·65	62·5	11·52	49·5
No. III. " . .	2·52	61·25	12·23	48·8
WINTER WHEAT.				
Alberta Red:				
No. I. Northern. .	3·68	64·5	10·71	58·8
No. II. " . .	3·50	64·0	10·69	53·5
No. III. " . .	3·65	63·25	10·93	50·2
Alberta White:				
No. I. . . .	4·01	62·5	10·47	55·4
No. II. . . .	3·97	61·2	10·77	54·9
No. III. . . .	3·65	61·2	10·37	52·2

As indicated by the weight of 100 kernels there is not much difference in the size of the kernels of the No. I. Northern received from Mr. Horn and that of the cargo lots; but there is considerable difference in the Nos. II. and III. grades. The No. III. of the cargo lots is a smaller grain and contains more shrunken grain, which probably accounts for the higher percentage of protein.

As the only method at present available of determining the relative value of a flour for bread purposes is by actual baking trials, the flours made from the wheats under discussion were baked in our own flour-testing laboratory, which is fully equipped with electric-proof and baking ovens so arranged that we have almost absolute control of the temperature, accurate balances for weighing flour and bread, apparatus for determining the volume of loaf of bread, expansion of glutens, &c. The work was done by a thoroughly competent person, who is constantly at the work and has developed that delicacy of feel which can only be acquired by constant practice.

In the baking trials 340 grams of flour and sufficient water, salt, sugar and yeast were used in making each loaf of bread. The yeast is used in what might be considered excessive quantities. The object is to cause the dough to rise as high as possible and thus bring out the strength or at least the expansive power of the flour.

The following table gives the weight of a loaf of bread from each of the different samples of wheat. The yield of bread was determined as accu-

[1] The mill used was made by the Allis-Chalmers Company, Milwaukee. It has a pair of six-inch corrugated rolls and a pair of smooth rolls of the same size. The flour is bolted through ordinary sized bolting cloth, but there are no aspirators. The machine is too small to secure absolutely accurate results. The wheats were milled as closely as possible without destroying the colour of the flour too much and the results should be comparative, although they do not represent exhaustive milling.

rately as possible; while it perhaps does not represent the yield that would be obtained in a large baking, the figures are comparative. The volume of the loaf was carefully determined by displacement of fine seed and is given in cubic centimeters. The comparative colour and texture of the bread and general appearance of the loaf are represented by figures; the No. I. samples of the different kinds of wheat being assigned the full 100 points and the others were scored in percentage of this:—

TABLE II.—*Weight, Size and Quantity of a Loaf of Bread from 340 grams of each kind of Flour.*

Grade of Wheat	Per cent. of Protein	Per cent. of Wet Gluten	Per cent., Water Absorbed	Weight of Loaf. Grams	Volume of Loaf c.c.	Quantity of Bread		
						Colour	Texture	Appearance
SPRING WHEAT.								
Winnipeg sample:								
No. I. Northern	9·98	33·10	67·2	511	2,540	100·0	100·0	100·0
No. II. "	10·02	31·20	67·5	503	2,520	102·0	98·0	98·0
No. III. "	10·08	30·17	68·0	496	2,770	102·0	96·0	96·0
Cargo lots:								
No. I. Northern	10·97	33·83	67·2	510	2,630	100·0	101·0	101·0
No. II. "	10·32	32·87	67·5	504	2,600	100·0	102·0	100 0
No. III. "	10·88	33·79	67·5	510	2,540	100·0	100·0	99 0
WINTER WHEAT.								
Alberta Red:								
No. I. . .	9·69	37·53	55·6	491	1,990	100·0	100·0	100·0
No. II. . .	9·54	32·83	55·6	481	1,900	95·0	96·0	100·0
No. III. . .	9·20	32·07	56·9	492	1,880	93·0	94·0	98·0
Alberta White:								
No. I. . .	8·31	27·97	50 3	472	1,480	100·0	100 0	100·0
No. II. . .	8·74	29·07	51·6	471	1,470	95·0	85·0	—
No. III. . .	8·88	27·90	51·6	482	1,600	97·0	104·0	108·0

As might be expected, the results show a great similarity in the quality of the bread obtained from the two lots of spring wheats. The samples representative of cargo lots are more uniform in quality than those obtained from the Chief Grain Inspector; this is doubtless due to the more thorough mixing of wheat produced from different localities and grown under varying conditions, thus obliterating the influences of environment.

The flour from the Alberta Red wheats contained as much gluten as the spring wheat flour, No. I. sample even exceeding all others; but they are much lower in water absorption, yield of bread and size of loaf. The volume of the loaf was approximately only 75 per cent. of that of the spring wheats. In our work with flour we have always found that, generally speaking, the small loaf was a heavy one, doubtless due to the lesser surface for evaporation of water. No attempt was made to compare the quality of the bread with that from the spring wheat, as they are quite different; the texture particularly was not so good, the bread was darker, and the loaf had not that bold, fine appearance characteristic of the bread from the spring wheats. In general it was more like that obtained from the *Durum* wheats.

The Alberta White wheat flour seemed to be very similar to that made from the same variety—*i.e.*, the Dawson's Golden Chaff, grown in Ontario; but it is not equal to the flour from the amber wheats or many other varieties produced in the older provinces. No explanation of the fact that the third grade of Alberta White wheat produced the largest and best loaf of bread is necessary, as these are not mixed samples.

In many cases spring wheats are ground and baked separately; but very frequently such grain is blended with the locally grown softer wheats of the country into which it is imported. These softer wheats have not sufficient gluten to produce a large well-raised loaf of bread and the texture is usually comparatively poor. On the other hand, the strong spring wheats yield a large, well-piled loaf of good texture, but the bread is inferior in flavour. The blending of the two wheats imparts to the bread made from it some of the desired properties of both, and the result is the production of a loaf of bread which, although not so large as that made from the spring wheat flour, is of good texture and flavour. To illustrate this point a series of blends were made with various proportions of the Manitoba spring wheat flour with that made from Ontario winter wheat. The bread from the Manitoba spring wheat flour was taken as the standard for colour, texture and appearance. No marks were given for flavour, as it was difficult to make an accurate judgment on this point. The results of the baking trials are given in the following table:—

TABLE III.—*Yield of Bread, Volume of Loaf, and Quality of Bread from the Blended Flour.*

Kind of Flour			Per cent. Water Absorbed	Weight of Bread. Grams	Size of Loaf c.c.	Quality of Bread		
						Colour	Texture	Appearance
Manitoba Per cent.		Ontario Per cent.				Per cent.	Per cent.	Per cent.
100		—	66·4	523	2,740	100·0	100·0	100·0
60	+	40	63·5	507	2,670	99·0	99·0	98·5
50	+	50	61·8	495	2,400	98·0	98·5	96·0
40	+	60	59·4	496	2,390	97·0	98·0	95·0
30	+	70	58·2	489	2,060	96·0	96·0	92·0
20	+	80	56·7	490	1,900	95·0	95·0	90·0
—		100	48·0	477	1,830	94·0	94·0	87·0

The yield of bread, volume of loaf and quality of the bread decreased with the increase of the proportion of the soft flour; if size of loaf is not an important point, it is evident that 50 or 60 per cent. of the soft flour can be introduced without seriously affecting the general result.

The Alberta Red wheat is used almost entirely for blending purposes. Even in Alberta it is not milled alone. As previously noted, the No. I. sample contains a very high percentage of gluten, much higher in proportion to the protein content than the spring wheat. But these results are reported after being repeatedly duplicated by an experienced person; while the percentage amount is undoubtedly high, they are as correct as can be got by the usual method of washing glutens.

To gather some data on the value of these wheats for blending purposes we have mixed varying proportions of the Alberta flour with Ontario winter wheat flour and carried it through the regular baking trials. In every case the bread obtained was much superior to that got from either flour alone. The results were very interesting; but although we have made several blends, they were all made with the wheat of one crop and with only one sample of soft flour, and we do not feel that we have sufficient data to warrant the publication of the results.

12. *The History of the Wheats.* *By* Dr. Otto Stapf.

When it was suggested to me that I should prepare a paper on the history of wheat, I hesitated, as I was aware that within the last twelve months or so this old and much discussed question had assumed a new aspect in consequence of Dr. Aaronsohn's remarkable discoveries, which were claimed to have solved the problem of the origin of wheat. Having had no opportunity of testing the validity of those claims, I was reduced to the necessity of keeping my paper within the limits of a review of the present conditions of the problem, with such observations and suggestions as I might have to offer from my own investigations. There were the latest researches respecting the earliest civilisations, particularly in so far as the Indogermanic peoples are concerned—researches connected with the names of Hahn, Hirth, Gradmann, Götz, and Otto Schrader. They had thrown much light on the first stages of agriculture, and incidentally the earliest history of the cereals, among which the wheats have always stood in the front rank. There were Buschmann's valuable contributions to our knowledge of prehistoric cultivations and the delightful essays on 'Wheat and Tulips' by Count Solms-Laubach, who by ingenious reasoning sought to transfer the origin of wheat to Central Asia and to a geological period more remote than had been previously suggested. There were also Schweinfurth's numerous articles on the economic botany of Egypt, ancient and modern, contributions of fundamental value but scattered through many and often almost inaccessible journals, and therefore not always turned to full account. Much of that literature, I reasoned, must have escaped the professional botanist and agriculturist, and it was time that it should be brought to their notice. It might arouse their interest and, beyond their circles, the interest of all who are accustomed to trace the present in the past, seeing in it merely the latest link in a long chain through which runs the never broken stream of life. It might fall on fertile soil and stimulate further and better organised research in a field which is full of abiding interest and practical promise, but also demands great versatility from the student and the co-operation of various departments of learning. But if I had still any doubts as to the appropriateness of dealing with this subject they were set at rest when almost at the last moment, thanks to the generosity of Professor Schweinfurth and Professor Max Koernicke, material came into my hands which went a long way to confirm Aaronsohn's discovery of the primitive or wild state of wheat.

I have used in the title of this paper the expression 'the wheats' instead of simply speaking of 'wheat.' This requires a few words of explanation. What we usually understand when we speak of 'Wheat' comprises a multitude of races, mostly of economic interest, which fall under one of the three groups of the Soft, the Hard and the so-called English wheats; or, to use their Latin designations, the *Vulgare*, the *Durum* and the *Turigidum* wheats. To them might be added as less common and economically less important wheats those of the *Compactum* and *Polonicum* group, popularly known as 'Dwarf' and 'Polish' wheats. With the exception of the last, all these together form, in the system devised by the prominent agrostologist, Eduard Hackel, the sub-species *tenax* of the species *Triticum sativum*. They are characterised, as the name *tenax* indicates, by having spikes with a tough spindle which, when mature, does not break up into joints and grains easily falling out from their husks or glumes. To these wheats proper are opposed the so-called Spelt wheats. The spindles of these break up into joints at maturity, the grains falling with their husks and being more or less difficult to separate from them. To this group we have to refer, of cultivated wheats—the Spelt proper (*Triticum Spelta*), the Emmer (*Triticum dicoccum*) and the One-grained

wheat or Einkorn (*Triticum monococcum*); further the two wild wheats, *Triticum ægilopioides* and *Triticum dicoccoides*. The macroscopic characters mentioned are, however, correlated with anatomical differences in the structure of the shell or pericarp of the grain, which still more accentuate the separation of the wheats proper and the Spelt wheats. From this standpoint the Polish wheat, which generally is treated as a distinct species, has to go with the wheats proper. Those are the principal kinds as they present themselves to the practical man without consideration of their taxonomic value. At present they are rather definite and distinguishable units, whatever their place and relative position in the evolution of the wheats may be. It need only be added that the various Spelt wheats differ more from each other than do the wheats proper. Those ten wheats, however, are not only fairly well definable, but they are also constant in the sense that we cannot turn Soft wheat into Hard wheat, or Spelt into Emmer; nor has it been proved so far that the two wild wheats can be transformed into their assumed cultivated representatives, as we can, for instance, convert the wild carrot into the garden carrot. But too much stress must not be laid upon that, as *Triticum ægilopioides*, the assumed primitive form of the Einkorn, has not been much experimented with, whilst *Triticum dicoccoides*, the supposed Emmer, was only rediscovered quite recently—having been known before solely from a single herbarium specimen—and is approaching now only its second harvest in the experimental grounds at Poppelsdorf, Bonn. In valuing the affinities of those wheats and tracing their descent, we have therefore to rely on the varying degrees of their structural resemblances, the nature of the differentiating characters, the presence or absence of intermediate forms, other than hybrids, and on analogies. We have seen that the wheats are divided into two groups by what is no doubt a practical difference of the highest order: the looseness or tightness of the grain in the husks, combined with the toughness or brittleness of the spindle on the one hand and the thicker or thinner grain shell on the other. These are three characters, each by itself, as characters in grasses go, apparently of considerable taxonomic value; but if we consider their part in the economy of those plants and the constancy with which they occur side by side, it becomes clear that they are really very closely correlated and behave functionally like one character. Among the wild grasses effective dissemination is provided for by a great variety of contrivances, and generally regulated so that the grains are dispersed singly or nearly so and at the same time protected by some covering until germination sets in. In the two wild wheats this is secured by the breaking up of the spindles on maturity, releasing thereby the individual one- or two-grained spikelets, and by the permanent enclosure of the grains in the husks. We find the same conditions in the grasses which are generally admitted as the primitive forms of rye and barley. In cultivated rye and barley the spindles are tough, and in rye and certain kinds of barley, the naked barleys, the grains are loose in the husks and separate easily, while in the other barleys the grains together with their special husks (flowering glume and pale) are loose in the spikelets. But although they are loose they are not loose enough to fall out very readily or without the application of mechanical pressure, such as is applied in threshing. This enormously facilitates reaping, and, where the grains are loose, their subsequent separation from the husks; it determines to a great extent the economic value of these cereals, while the same conditions would naturally be disadvantageous or even fatal to plants in their natural states. And what is true of the cultivated and the wild ryes and barleys is *mutatis mutandis* true of cultivated and wild rice and of the cultivated and wild millets. If we now apply the same reasoning to the wheats of the *tenax* group—that is, the wheats with tough spindles—this character, with its correlations, loses practically all its value

as a guide for taxonomic purposes, and we are thrown back, after eliminating it, on what is left of structural differences or resemblances. It is true a great deal has been said about the sexual affinities of the wheats, and the long series of experiments by the Vilmorins, Beyerinck, Rimpau, and others have thrown a flood of light on the facilities of the wheats for hybridisation. Much has been made especially of the difficulty of crossing Einkorn with other wheats, and its position as a distinct species has on that account been universally admitted. But common wheats have been successfully crossed with, structurally, much more remote species of *Ægilops* and even with rye. Moreover, so-called generic hybrids are becoming more and more frequently known, while, on the other hand, many species structurally very similar resist all attempts at crossing. Therefore the argument from sexual affinity to genetic affinity loses very much of its force; in fact, the latter and its degrees will always have to be inferred in the first place from structural resemblances, the term 'structural' including external as well as anatomical characters. I will now set out briefly the genetic relations of the wheats as they appear to me viewed from that basis, and I will start from the two wild wheats, *Triticum ægilopioides* and *Triticum dicoccoides.*

Triticum ægilopioides (Balansa) is a species ranging from the Balkan Peninsula and the Crimea to Syria and Upper Mesopotamia. Koernicke distinguishes two races, a weaker one from the Balkan Peninsula and a more robust one from the Asiatic part of the area. The structural resemblance of this species and the Einkorn, *Triticum monococcum*, is so complete that it is quite evident and generally admitted that the Einkorn has originated from *Triticum ægilopioides.* It has given rise to few races, and such as there are point rather to the Asiatic variety than to the European as the primitive form. The only obvious change it has undergone in the process of domestication is in the great reduction or almost complete suppression of the hairs of the spindle, which in the wild form are long, white, and altogether conspicuous. I may at once remark that the same applies more or less to most of the domesticated wheats, and it may be that this character also enters in the correlation-plexus, which is connected with the dissemination of the wild wheats and which I mentioned before. Einkorn is, no doubt, one of the oldest wheats. Schliemann found its grains in considerable quantity in the ruins of Troy, in the so-called second town, which is approximately dated at 2000 B.C.; it has also been found in neolithic strata in Hungary and Switzerland. The ancient Greeks knew it as Τίφη and Ἁπλῆ Ζεά; but the Romans do not seem to have cultivated it, except in Upper Italy, and if the Spaniards received it early, as seems to be the case, it must have been by way of Gaul. It is still a common cereal with them; otherwise it is grown in France, Switzerland, Wurtemberg, Thuringia, and in some parts of the Balkan Peninsula. It does not seem to have spread eastward from its original home.

The only other wild wheat is *Triticum dicoccoides.* So much turns on the discovery of this species that a short account of it is necessary. In 1855 Theodor Kotschy collected a specimen of *Triticum* on Mount Hermon, in Syria. It evidently did not strike him as remarkable, as he does not mention it in his description of the flora of that mountain; nor was it noticed by any other botanist until in 1889 the late Professor Koernicke announced at a meeting of the Niederrheinische Gesellschaft at Bonn that he had found the primitive or wild state of his *Triticum vulgare* (which includes all the wheats, with the exception of the Einkorn) in Kotschy's plant from Mount Hermon. This he named *Triticum vulgare* var. *dicoccoides.* Nothing beyond a bare note stating this announcement was published at the time. But when, a few years ago, Professors Ascherson, Schweinfurth, and Warburg made arrangements with a young Palestine farmer and botanist, Mr. Aaronsohn, for the agricultural exploration of his

country, they also called his attention to Kotschy's *Triticum*. In June 1906 we find Aaronsohn travelling from Lake Tiberias to Mount Hermon in search of the wheat. On the 12th of that month he discovered the first colony of it a few miles to the north-west of the site of ancient Capernaum, on Lake Tiberias. It was growing in scattered tufts, associated with *Echinops*, *Ononis*, *Prosopis*, &c., and nearly always with *Hordeum spontaneum*, the wild barley. Crossing the Jordan and travelling towards Mount Hermon he again came across it near Arny, on the southern end of the mountain, and then in many localities on the eastern slopes of Mount Hermon, in places ascending to over 2,000 m.; also on the northern slopes above Rascheia, where Kotschy found it fifty years previously, and from there eastwards to where the plateau extending towards Damascus begins. Here on Mount Hermon it was frequently associated with *Triticum ægilopioides*, and near Rahle both species formed complete fields, with *Triticum dicoccoides* as the predominant partner. Last year Aaronsohn discovered *Triticum dicoccoides* in the country of Gilead, east of Jericho, growing under conditions similar to those in the Hermon district. One feature of Aaronsohn's specimens is their want of homogeneity. This was already observed by the late Professor Koernicke, who, in a letter to Professor Schweinfurth written shortly before his death, said that the diversity of forms in Aaronsohn's material of *Triticum dicoccoides* was quite bewildering. This will have to be taken into account in estimating the bearing of Aaronsohn's specimens on the question of the origin of wheat, particularly when the results of the Poppelsdorf experimental series come to be worked out. Aaronsohn not only observed *Triticum dicoccoides* growing in intimate association with *Triticum ægilopioides*, but it seems (in one locality) also in the neighbourhood of wheat-fields. The latter is not quite clear, but it is of the greatest importance to be certain about it, as the introduction of hybrids of *Triticum dicoccoides* and *Triticum durum* into the Poppelsdorf experiments might considerably affect their validity.

On comparing the specimens of *Triticum dicoccoides*, which I have seen myself, with our cultivated wheats, I was at once struck by the great resemblance of a glabrous form to a Hard wheat in the Kew collections from Urumiah in Persian Kurdistan. There was, no doubt, the differential correlation-plexus which separates the wheats proper from the Spelt wheats, and there was also the roundish cross-section of the grains of the Urumiah wheat against the triangular one of the grains of *Triticum dicoccoides*, a character very likely correlated with the respective looseness and tightness of the grains in the husks. But apart from that and the somewhat longer and considerably rougher awns in the *dicoccoides* specimen, the resemblance, not so much of the whole spike but of some of the detached spikelets, amounted almost to identity. Even the villosity of the spindle edges was only slightly less pronounced in the Urumiah wheat than in the wild state. Unless we have here, in the glabrous *dicoccoides* specimen, a cross of *Triticum dicoccoides* with *Triticum durum* (in which case, however, neither the fragility of the spindle nor the tightness of the grain in the husks nor the shape and anatomical structure were affected), the conclusion seems irresistible that this *Triticum dicoccoides* is indeed the primitive form of the Hard wheats. Most of the other specimens of *Triticum dicoccoides* which I could examine corresponded to the coarser, pubescent, dark, and black-awned races of Hard wheats, such as '*africanum*,' '*niloticum*,' or '*libycum*,' although in some cases the approach was not so strikingly close. But if *Triticum dicoccoides* gave rise to the Hard wheats, it also gave rise to the Emmers, only that in the Emmers the spindle remained brittle, the grains tight in the husks, and the grain shell thin, while the spindle hairs were much reduced or all but disappeared, so that the Emmers represent an evolution parallel to that of the Einkorn. The common origin of the Hard

wheats and Emmers from the wild wheat of Palestine also suggests the possibility of the evolution of Hard wheats from Emmers as the more primitive of the two series. Schweinfurth not only suggested this a few years ago, but he actually found in wheat from the tombs at Abusir in Egypt a few Emmer heads with partially tough spindles. More than that, the spindles were villous along their edges, as in some of the Hard wheats. Hard wheat represents no doubt one of the oldest races of wheat, although so far not many authenticated cases of very old finds have been recorded. Still it has been discovered in several Egyptian tombs, and at Hissarlik in a stratum overlying the ruins of Troy. Being essentially a warm-country wheat, it is not surprising that it has not been met with in the prehistoric strata of Central Europe. But probably this wheat spread early over the whole of North Africa, where, as also in Spain, it is represented by very numerous races. Hard wheat is also found in Abyssinia, and eastwards as far as India, and, what is significant, accompanied in both countries by Emmer and forms intermediate between Emmer and Hard wheat. It may also have reached Southern Europe in remote times; but there seems to be no definite evidence, the earliest reliable records dating from the sixteenth century.

We are better informed as to the early history of Emmer. According to Schweinfurth, Emmer and six-rowed barley were the common cereals of ancient Egypt, where the former has been found in considerable quantities and in an excellent state of preservation. At Abusir, for instance, Emmer chaff was used along with other materials for filling up the tombshaft, and at Gebelên, in the tomb of Ani, Maspero found satchels made of grass and filled with fruits and Emmer spikes. These finds take us back to about 2000 B.C. Emmer is also recorded from the neolithic lake dwellings at Wangen and from those of Auvernier and the Petersinsel, all in Switzerland, the last two being of Bronze Age. More recent but still dating back to the first centuries of our era is the Emmer of Aquileia. The ancient Romans and Greeks knew it, and there is now little doubt that it was the *Adoreum* or *Far* of the Romans and the Ζεά or Ὄλυρα of the Greeks, or at least of most of the Greek writers. In the famous Codex of Dioscorides at Vienna, an illustrated manuscript of Dioscorides' *Materia Medica*, a wheat is figured to illustrate the paragraph on Χόνδρος, a kind of pearl-barley prepared from the Ζεὰ δίκοκκος and this wheat is apparently an Emmer with a somewhat stout head. It is certainly not a Spelt proper, *Triticum Spelta*, which is usually considered to have been Ζεά or Ὄλυρα of Greek literature. To-day the cultivation of Emmer is confined in Europe to a few districts in South Germany, Switzerland, Spain, Italy, and Servia. In Egypt we find it mentioned under the name of *Triticum Spelta* as being grown near Alexandria until the forties of the last century; but since then it seems to have disappeared from there as from other parts of the Orient. On the other hand, it still has, as already stated, a hold in Abyssinia with its old and conservative civilisation, and to a very limited extent in India, where it was probably introduced long ago by Mohammedan traders. The Hard wheats lead us naturally to the so-called English wheats, or the *Triticum turgidum* stock, and the Polish wheats.

The English wheats, like the Hard wheats, are warm-country wheats, and have no doubt the same origin. Schweinfurth mentions *Triticum turgidum* among the cereals of ancient Egypt, and Unger believed he recognised it in a spindle fragment which he found in a brick from the walls of the ancient town of Eileythia. Beyond this there is practically nothing known about its early history. It has probably originated along with the Hard wheats. Still less is known in this respect about the Polish wheats. Koernicke, in his 'Handbuch der Getreidekunde,' considered it as a very distinct sub-species, which he opposed to all the other wheats taken

together; Hackel even treats it as a distinct species. But in a posthumous paper just published Koernicke recognises the Polish wheats as mutations from Hard wheats, characterised by the over-development of the outer or involucral glumes; various North African Hard wheats certainly support this view very strongly. Polish wheat is first mentioned in the seventeenth century; although it may not have been known to the Greeks, it is probably of much earlier origin than is generally assumed, as it is represented in Abyssinia by several marked races. Outside of Africa its cultivation is confined nowadays to Italy and Spain.

We have so far accounted for the two wild wheats, the Einkorn, the Emmer, the Hard, the English, and Polish wheats. Their relations and early history may be considered as fairly established. It is different with the Soft and the Dwarf wheats, which have this in common and in contradistinction from the Hard wheats, that the outer or involucral glumes are keeled only in the upper part but rounded below. The Soft wheats are extremely numerous and show perhaps a greater range of variation than the others. They occur in our day wherever wheat is grown, although they are not always the predominant race. They are believed to have formed the bulk of the 'Πυρός' of the ancient Greeks and of the *Triticum* of the Romans. Many finds in neolithic strata all over Europe have been assigned to them, so that the Soft wheats would appear to be as old as any. But there is this double difficulty, that the descriptions of the ancients are too vague to guide us, while the actual finds consist exclusively of loose grains, varying very much in size and shape. Buschmann enumerated not fewer than twenty-two places in Europe where prehistoric grains assigned to *Triticum vulgare*—that is, the Soft wheat group—had been discovered; of these more than one-half (thirteen) belong to the neolithic age. Considering, however, the difficulty of identifying loose grains of these wheats, particularly if not very well preserved, we have to be on our guard against hasty conclusions concerning the dates and the extent of their cultivation in those remote times; in any case, they do not offer us a clue to their descent. Structurally they are, no doubt, closely allied to the Hard wheats, but I doubt whether they have the same origin. Schweinfurth remarks that all the old Egyptian grains of this class which he saw were remarkably small. The same can be said of most of the neolithic grains of Central Europe, and of the two English prehistoric samples in the Kew Museum, while most of these grains are at the same time comparatively stout. These old small-grained races are probably nearer to the primitive form, but if so the latter has not yet been discovered.

With respect to the Dwarf wheats we are in a similar position. Although at present nowhere extensively grown, to judge from their present and past distribution they must have once been grown over a much larger area. They are said to have been found in several neolithic localities in Central Europe; here again the finds, with two exceptions, consisted of grains only. These exceptions are some ears and spikelets from the Swiss lake dwellings, described by Heer as *Triticum vulgare antiquorum*, and some spikelets from the same localities referred by him to *Triticum compactum*. The latter resemble, according to Heer, the ordinary Dwarf wheat of modern Switzerland so much that he did not hesitate in identifying them with it. The other, however, his *Triticum vulgare antiquorum*, is quite distinct. The ears, although not intact, are splendidly preserved as far as they go. Their grains—usually three to four in each spikelet—are very small and stout. Other still more rounded grains from the neolithic and Bronze period of Central and South Europe have been described as *Triticum compactum* var. *globiforme* by Buschmann. Here again we have, as in the Soft wheats, an indication that the primitive form must have been, unlike *Triticum dicoccoides*, a small- and probably stout-grained *Triticum*

at present unknown. Both the Soft and the Dwarf wheats date back to equally remote times, both show a similar distribution in the past, and their general structural resemblance is sufficiently great to suggest a common origin. What it was we know not. Their primitive form will probably one day be traced back to a third species of wild wheat and to an area not very far distant from that whence the Emmer and Hard wheats came. Here at any rate is ample scope for further exploration.

The last of the wheats with which I have to deal is the Spelt proper, *Triticum Spelta*. Its origin has so far been quite obscure. It is mostly considered to have descended from Emmer, although the structure of its axis and its glumes lend little support to that theory, which probably had its origin in the early confusion of the popular names of the Spelt wheats. Spelt has so far never been found in any of the prehistoric settlements. Even its name Spelta was unknown until A.D. 301, when it appears for the first time in an edict by the Emperor Diocletian. It probably came to the Romans from the Germans, as Gradmann suggested in 1901. Since then, in a monograph, 'Der Dinkel (Spelt) und die Alamannen,' he has produced strong evidence that Spelt was the staple grain of the Alamans, who brought it with them into South and West Germany from their old home east of the Elbe. From there it would have spread to the Alps, Italy, France, and Northern Spain. Gradmann's expression 'east of the Elbe' has evidently to be taken in a wide sense, as there is no grass in Eastern Germany or Western Russia from which Spelt could have descended. But still further east, or rather south-east, around the northern shores of the Black Sea, whence the Alamans may very well have come originally, a species of *Ægilops* occurs, *A. cylindrica* or *Triticum cylindricum*, which comes structurally so near to the Spelt that I feel almost convinced that it is the primitive form of the latter. The usual slender forms of *Triticum cylindricum* are perhaps not so suggestive in this direction; but occasional stouter specimens approach very closely to it in the nature of the spindle, the texture and the cut of the outer glumes, and the curiously protruding inner or floral glumes. Moreover there is at Kew a specimen of *Triticum cylindricum* raised from seeds found among grain refuse in the Leith Docks, near Edinburgh, which might be taken for a pubescent but otherwise almost typical Spelt, except for the characteristic awns of the terminal spikelet. This theory of the descent of Spelt from *Triticum cylindricum* does not exclude the possibility of early crossing with true wheats, as some of the peculiarities of Spelt suggest. For all we know the Leith casual may be a cross between *Triticum cylindricum* and a pubescent true wheat, similar to the hybrid of *Triticum Spelta* and a pubescent unbearded wheat, described by Koernicke as *Triticum Spelta* var. *recens*.

To summarise briefly, we have traced the wheats to four primitive types: (1) the Einkorn, to *Triticum ægilopioides*, with its original home in Asia Minor and the north-eastern Balkans; (2) the Emmer and the Hard wheats, including the English and Polish, to *Triticum dicoccoides*, in Palestine; (3) the Soft, and probably also the Dwarf wheats, to a still unknown species, either in Syria or in Mesopotamia; and (4) the Spelt, to *Triticum cylindricum*, in an area extending from Bulgaria through Roumania to Southern Russia. From this standpoint the practical division into Spelt wheats and wheats proper breaks down entirely. Einkorn and Spelt proper, with their respective primitive forms, will have to stand as distinct species in any case; while it may be left an open question whether all the others should be treated under one or two species until we know the primitive form of the Soft and Dwarf wheats, and are able to gauge its taxonomic value as compared with *Triticum dicoccoides*.

I have so far tried to remain on ground which allows us to work with tangible material and by way of comparing actual specimens. It will now

be interesting to sift the available experimental evidence and perhaps to start a new series of experiments on the basis of my propositions. Above all, however, it is desirable that the efforts to trace the distribution of the primitive wheats and discover new wild forms should be continued. In the first place, there can be now no doubt where to look for the latter. The statement of the Assyrian historian Berosus that wheat grew wild on the banks of the Euphrates, and Olivier's observation to the same effect made more than 2000 years later, cannot, after Aaronsohn's discoveries, be treated any longer as negligible, especially as Olivier's location of the place where he found wild wheat associated with wild barley and 'Spelt' is so precise that there ought to be no difficulty in visiting and examining it again. Another point which I would impress is the necessity of collecting without delay good samples of all the wheats—whole plants, as well as grains—which are grown in the Old World, particularly in the districts not yet much affected by the introduction of modern races. Many of the more primitive races are no doubt still in cultivation, and if not secured in time they will be lost for ever. The Balkan Peninsula, Asia Minor—in fact, the whole of the Orient—should be searched, and the same applies to Abyssinia, to Central Asia, and China. I have so far not mentioned the Chinese wheats, although wheat is grown more extensively in China, particularly in the north and west, than is generally understood, and although it has been known to the Chinese for a very long time—at so early a period, indeed, that Count Solms-Laubach saw in this fact one of the arguments for his contention that the wheats were of Central Asiatic origin. Besides making systematic collections of the wheats grown at present, it will also be necessary to search for, preserve, and carefully study every spike, spikelet, or grain sample found in the course of excavations of ancient sites, and to catalogue, examine, and compare whatever there may exist of old pictorial representations of cereals. We shall then, by the concentrated efforts of the collector, the botanist, and the archæologist, be in a better position to reconstruct the process of evolution which has led from a few wild grasses to the vast number of cultivated races which to-day we comprise under the name of wheats. This is a process which claims the attention not only of the botanist but of all of us who, beyond our professional spheres, are accustomed to give a thought to the wider and deeper problems of the history of civilisation. The evolution of the cereals occupies the foremost place in the rise and onward march of agriculture all over the world. That of the wheats—with their immediate allies, the barleys and ryes—is especially closely associated with the white races; it is like a keystone in their making, it runs in their blood. With the ancients the cereals were the gifts of the gods. Isis gave wheat and barley to Egypt; as Demeter she took them to Greece, as Ceres to Latium. A wreath of wheat ears crowned her head, in Egypt as well as in Hellas and Rome. To go to the other end of the old Old World wheat area, the Chinese also received it 'from Heaven,' or, as other legends have it, from their half-mythical Emperor Shen-nung, who in the very dawn of Chinese history taught them to till the ground and raise the 'wu ku,' the five grains. Among them, holding the second place, was 'mai,' which originally stood for wheat and barley, and later on, according to Bretschneider, with or without the qualifying 'siao' (little), for wheat alone. Thus as the Egyptian myths made Isis introduce wheat and barley simultaneously, so in China the 'mai' which the Emperor Shen-nung sowed covered both. Similarly the Ζεά the primitive wheat of ancient Greece, is etymologically equivalent to the sertic and avedic yava, which in another direction gave rise to 'djau,' the Persian name for barley, while the Latin *far*, the synonym of Ζεά, corresponds to the Gothic *barizeins* and Anglo-Saxon *bere* for barley. This is remarkable, and becomes very significant in the face of Aaronsohn's and Olivier's

observations to the effect that the wild wheat and the wild barley are closely associated in their natural habitats. It is like an echo from the dim mythical past, telling us that wheat and barley are twins of one home and one age. Myths are like dreams, but even dreams have their kernels of truth. Diodorus Siculus, a Greek historian and contemporary of Cæsar, records the following legend: 'Osyris, whose home was at Nysa, in that part of fertile Arabia which is not far from Egypt, loved agriculture, and he found the vine in the neighbourhood of Nysa. This shrub was growing there wild, abundant, and hanging from the trees. Here also Isis found wheat and barley, growing haphazard in the country among the other plants, but unknown to man.' Diodorus further says that there was at Nysa a column, with a hieroglyphic inscription commemorating Isis' discovery; the inscription ran: 'I am the queen of all this country. I am the wife of Osiris and his sister. I am she who has first taught man to know the cereals. I am she who resides in the constellation of the dog. O rejoice, Egypt, thou my nurse.' Where is, then, this fabulous Nysa, the home of wheat and barley? Pliny identifies it with Scythopolis, but Scythopolis is none other than Bethshean, a town west of the Jordan and not many miles south of the Sea of Galilee, in the trend of the same hills which, fifty miles further north, to this day bear the wild wheat and the wild barley 'growing haphazard in the country among the other plants.' Where, if not here, has ever any myth come true? Isis' column at Nysa has fallen, but her golden treasure has borne millionfold and conquered the world wherever the white man went; when you go through your wheat-fields and think of Isis, your great benefactress, you will hear out of the rustle of the ears the gentle voice of the dark-eyed goddess: 'Rejoice, rejoice.'

Concluding Remarks.

Various points were dealt with in the discussion which took place after the speakers had summarised their communications; for the most part these are covered by the Papers printed above.

It will be clear from these how numerous are the issues raised, how important and how infinitely difficult are the problems which still have to be solved before it can be said that we understand wheat; breed, soil, climatic conditions, public requirements, and economic considerations are all factors of primary importance which not only must be taken into account but often balanced against one another.

The Rothamsted experiments afford much information as to the food requirements of the wheat plant, but the data may be said to be chiefly statistical. At present we know little or nothing of the actual composition of the grain; we are unable to say to what extent it always approaches a certain general average. We are unable to estimate the starch in wheat with any degree of accuracy and we determine nitrogen in it without any reference to the forms in which the nitrogen is present. A great field of useful work is open to those who will endeavour to devise analytical methods which will make it possible to discuss the food value of cereal products in relation to their ultimate composition.

The discussion to which the determination of the strength of flour has given rise is of great interest in many respects, but there is considerable difference of opinion between those who look at the subject from the practical side and those who are seeking to give an explanation of the mysterious behaviour of gluten. Great stress is laid upon the amount and quality of the mineral matters in flour, but in practice, in making bread, a considerable amount of salt is added and therefore the mineral matter in the flour cannot alone be counted as effective.

The question, after all, is one of behaviour under practical conditions.

Dr. Hardy argues that gluten *per se* has no tenacity, but this is equally true of clay—probably the tenacity of clay is the tenacity of water: the individual particles are associated with water molecules and these water molecules serve to cement the particles together—in flour, as in clay, the individual particles differ and there are differences between flours as there are between clays. At present strong flours are fashionable and are preferred, but there is no proof that they are of special value except from the point of view of fashion. Strong flours cannot be grown everywhere, and the question will arise whether, instead of seeking to produce strong flours everywhere, it will not be rather a question of so improving the baker's art that he will be able to avail himself more fully than is now the case of the various qualities of flour that may be produced; it is difficult to imagine that the food value of different flours can be very different.

When the time comes, in Canada and elsewhere, that the soil is less suitable for wheat cultivation, when the country is more fully developed, it will be necessary to introduce a more complicated system of agriculture; wheat will no longer receive almost sole attention, although it should always remain the most important crop. The farmer should be prepared and willing to take advantage of scientific knowledge in anticipation of such a change.

In closing the meeting, the Chairman said that one effect of the discussion should be to impress on the city of Winnipeg that the problems of agriculture deserved to be taken seriously in hand. Many who had been in the city during the week had been impressed by the way in which the streets and roads were cared for. Winnipeg, he said, taxed itself to grow fine roads; the question he desired to raise was: Should it not tax itself to grow fine wheat? He thought it was the one place where a tax might be imposed on wheat in order to support a real University in which wheat could be studied from every possible point of view. He thought no better form of insurance could be effected and he ventured to take the opportunity of making the suggestion in all seriousness to the city of Winnipeg.

APPENDIX B.

WINNIPEG: 1909.

Narrative of the Meeting of the British Association at Winnipeg, Manitoba, and Itinerary of the Party invited to take part in the Excursion through the Western Provinces after the Meeting.

THE Seventy-ninth Annual Meeting of the British Association for the Advancement of Science was held at Winnipeg, Manitoba, Canada, on the invitation of the city of Winnipeg, with the support of the Royal Society of Canada, the Historical and Scientific Society of Manitoba, and the Faculty of Science of the University of Manitoba.

The work of organisation at home was entrusted to a special Committee of the Council, consisting of Mr. Francis Darwin (President), Professor Sir J. J. Thomson (President-Elect), Major P. A. MacMahon and Professor W. A. Herdman (General Secretaries), Professor J. Perry (General Treasurer), Professor H. A. Miers, Professor A. C. Seward, and Dr. H. T. Brown. At Winnipeg a Local Executive Committee was formed, of which the Mayor of the city acted *ex officio* as Chairman. Mr. J. H. Ashdown occupied this position until the close of the year 1908, when Mr. W. Sanford Evans took office. The details of organisation were carried out under the direction of two of the Honorary Local Secretaries, Professors M. A. Parker and Swale Vincent; the other Honorary Local Secretaries (his Worship Mayor Evans and Mr. C. N. Bell) acted in an advisory capacity.

The Dominion Government contributed \$25,000 towards the expenses of the Meeting, the province of Manitoba \$10,000, the city of Winnipeg \$7,800, the provinces of Alberta, British Columbia, and Saskatchewan \$5,000 each, and smaller grants by other public bodies made up a total contribution of about \$60,000. A sum of \$15,565 was contributed out of the local funds towards the travelling expenses of the Officers of the Association and of the Sections, distinguished Foreign Guests, Members of the General Committee, and Members selected by the General Officers, principally on the nomination of the Sectional Committees.

The number of oversea members to whom tickets were issued for the Meeting was 475.

By a special arrangement with the American Association for the Advancement of Science, the President, Vice-Presidents, and Officers of that Association were invited to attend the Meeting of the British Association as Honorary Members for the year, and all Fellows and Members of the American Association were admitted Members of the British Association on the same terms as Old Annual Members.

The following is an analysis of the tickets issued for the Meeting:—

Old Life Members	117
New Life Members	13
Old Annual Members	153
New Annual Members	162
Associates	789
Ladies	90
Members of American Association, &c.	137
Foreign Representatives	7
Total	1,468

Arrangements were made with the Allan, Cunard, Canadian Pacific, and White Star-Dominion Steamship Companies, whereby oversea Members, on payment of the minimum first-class rate, single or return, were allotted superior accommodation on the steamers so far as possible. Arrangements were made with the Canadian Pacific and Grand Trunk Railway Companies and other companies working in conjunction therewith, whereby tickets for the return journey between Quebec, Montreal, or other East Coast ports and Winnipeg were issued by various routes at special rates, usually approximating to ordinary single fares, with special privileges as regards stopping over *en route.* Similar privileges were granted for side trips and for travel westward from Winnipeg to the Pacific Coast. The special tickets were issued on presentation of a 'transportation certificate,' signed by the Secretary of the Eastern Canadian Passenger Association, countersigned by the Assistant Secretary of the British Association, and issued to Members with their tickets of membership. Special facilities were also arranged for Canadian and American Members.

On the outward journey a number of Members availed themselves of facilities to visit Macdonald College, near Montreal, McGill University, and other institutions, and a party of geologists was enabled to visit the centres of mining activity at Cobalt and Sudbury.

The Winnipeg Meeting followed the normal course of annual meetings, with the exception that in place of the usual lecture to artisans two popular lectures to the citizens were provided. These were on 'The Chemistry of Flame,' by Professor H. B. Dixon, on Monday, August 30, and 'The Pressure of Light,' by Professor J. H. Poynting, on Wednesday, September 1. These lectures, as well as the President's Address and the usual two Evening Discourses (on 'The Seven Styles of Crystal Architecture,' by Dr. A. E. H. Tutton, and on 'Our Food from the Waters,' by Professor W. A. Herdman), were delivered in the Walker Theatre. As this building has accommodation for upwards of 2,000 persons, it was found possible to admit a limited number of the general public to the President's Address and the discourses, and to reserve a limited number of seats for Members on the occasion of the popular lectures. Full advantage was taken of these opportunities, and the theatre was well filled on every occasion.

At the Opening Meeting the Chair was taken by Dr. G. Carey Foster, in the unavoidable absence of Mr. Francis Darwin, the retiring President, from whom a letter was read by Major MacMahon, introducing Professor Sir J. J. Thomson as the new President, who then delivered his Inaugural Address. A vote of thanks for the Address was moved by his Worship the Mayor of Winnipeg, Mr. W. Sanford Evans, and seconded by the Right Hon. Lord Strathcona, High Commissioner for Canada. The vote of thanks for Dr. Tutton's discourse was moved by the Rev. George Bryce, D.D., who, as President of the Royal Society of Canada, took the opportunity of welcoming the Association in the name of that Society. The vote was seconded by Professor Alexander Johnson, F.R.S.C., of McGill University. At Professor Herdman's discourse the Hon. R. P. Roblin, Premier of Manitoba, took the Chair, and the vote of thanks was moved and seconded

respectively by Professor McMurrich and Mr. J. Stanley Gardiner. At Professor Dixon's lecture the Hon. A. C. Rutherford, Premier of Alberta, was in the Chair. At Professor Poynting's lecture the President took the Chair, and Sir J. Larmor and Dr. W. N. Shaw moved and seconded the vote of thanks.

The Drill Hall, Broadway, was fitted and used as the reception-room and writing-room. It stands facing the University of Manitoba, in which were the administrative offices, the meeting-rooms of the General Committee, Council, and Committee of Recommendations, and also those of Sections B, D, G, I, and K. Section A met in Wesley College; C in Isbister School; E and F in Manitoba College; H in Carlton School; L in the Legislative Chamber, Parliament Building; and Sub-Section K (Agriculture) in Alexandra School.

The Concluding Meeting on Wednesday, September 1, was held in the Legislative Chamber. A resolution of thanks to the Dominion, the Province, and the City for their generous contributions towards the expenses of the Meeting was moved by the President, and responded to by the Hon. R. P. Roblin, Premier of Manitoba, and Mr. Alexander Haggart, M.P. A resolution of thanks to the Mayor, the Council, and the Citizens of Winnipeg for the reception and facilities given to the Association was moved by Sir William White, and responded to by his Worship the Mayor. A resolution expressing appreciation of the work of the Local Executive Committee and Officers was moved by Major P. G. Craigie, and responded to by Principal D. W. McDermid. A resolution of gratitude to the Citizens of Winnipeg for the hospitality shown to visiting Members was moved by Sir Charles Watson, and responded to by Mr. D. C. Cameron, Chairman of the Hospitality Committee.

The following entertainments were on the official programme: Garden Parties by the Commissioner of the Hudson's Bay Company and Mrs. Chipman, at Lower Fort Garry, on August 26; by Principal and Mrs. W. J. Black, at the Agricultural College, on August 30; by the Hon. Chief Justice and Mrs. Howell, at their residence, Carlton Street, on August 31; and by Mr. and Mrs. Aikins, at their residence, Riverbend, on September 1. An afternoon entertainment was given by the St. Charles Country Club on August 27. His Honour the Lieutenant-Governor (Sir Daniel Hunter Macmillan) gave an evening reception on August 27, the officers and men of the Royal Canadian Mounted Rifles a gymkhana on August 28, and the Local Executive Committee a conversazione in the Royal Alexandra Hotel on August 30. Among other entertainments was a garden party at Silver Heights, given by Lord Strathcona, in whose reception, on his arrival in the city, the President had taken part. A number of local clubs and other institutions opened their doors to Members.

Excursions were arranged on Saturday, August 28, to the wheat-fields, Portage la Prairie; to the City hydro-electric plant on the Winnipeg River, Point du Bois; and to Winnipeg Beach, Lake Winnipeg (whole day); and to St. Andrew's Locks, Red River, and to Stony Mountain and the municipal stone quarries (half-day).

Western Excursion.

A special train on the Canadian Pacific and Canadian Northern Railways was provided by the liberality of the three western provinces of Saskatchewan, Alberta, and British Columbia for a tour after the Meeting, from Winnipeg to Vancouver (for Victoria) and back. The accommodation on this train was limited exclusively to 200 invited guests, and it was arranged that 150 of these (including twenty-five ladies) should be oversea Members invited by the Local Executive on the nomination of the Winnipeg

Committee of the Council, on whose instruction the General Secretaries had previously ascertained the names of those who, out of a selected list, desired to join the party. The remaining fifty were to be Canadian and American Members invited by the Local Executive.

The special train left Winnipeg, on the Canadian Pacific line, at midnight on Thursday, September 2. It consisted of nine sleeping-cars, two dining-cars, and a baggage-car, this being the heaviest train which it was possible to handle over the mountain section of the line. It was in charge of Mr. H. W. Brodie, Assistant Passenger Agent for the Western Division, to whom, with his assistant, Mr. W. Trapp, the party owed much for the comfort of the journey.

On September 3 a stop of five hours was made at Regina, Saskatchewan. Here the party was received by his Honour Amédée E. Forget, Lieutenant-Governor of the Province, and the gentlemen were entertained to luncheon in the City Hall. His Worship the Mayor, Mr. Williams, welcomed the party, and the City Clerk, Mr. J. Kelso Hunter, read a civic address of welcome. The President replied. The Hon. Walter Scott, Premier of the Province, then spoke on behalf of the Province, and Major MacMahon responded. Meanwhile the ladies had been entertained by Madame Forget at Government House, and the party subsequently reassembled at the barracks of the Royal North-West Mounted Police, where it was received by the officers of that force.

A further stop was made in the evening at Moose Jaw, Saskatchewan, where the party was conducted to an archway emblematic of the agricultural prosperity of the region, and an address of welcome was given by his Worship the Mayor, Mr. J. E. Hopkins, and responded to by the President. The party was subsequently entertained to dinner, when speeches were delivered by Mr. Thomas Miller, President of the Moose Jaw Board of Trade; Mr. Wm. Knowles, M.P.; Mr. E. N. Hopkins, President of the Saskatchewan Grain Growers' Association; Mr. E. J. Chegwin; Mr. G. E. Tuxford; and Mr. H. McKellar, Commissioner of the Board of Trade; and, on behalf of the Association party, by the President, Dr. W. N. Shaw, and Sir Duncan Johnston.

At Gleichen, on Saturday afternoon, September 4, a number of Blackfoot Indians met the train, and were received by the party. A collection was subsequently made for them, and forwarded to the Hon. David Laird, Indian Commissioner. It was expended in a gift of tea, sugar, and tobacco, for which the Head Chief of the Blackfoot Tribe, Yellow Horse, conveyed his thanks to the Association through the Commissioner.

At Calgary, Alberta, which was reached later in the afternoon, conveyances were provided to conduct the party on an inspection of the city and its environs. The visitors were subsequently entertained to dinner, when speeches were delivered by his Worship the Mayor, Mr. R. R. Jamieson; the Hon. W. H. Cushing, Minister of Public Works for the Province of Alberta; and Mr. R. B. Bennett, K.C., M.P.; and, on behalf of the party, by the President, Dr. A. D. Waller, Major MacMahon, and Sir William White.

On Sunday, September 5, the train entered the Rocky Mountains, and halts of several hours were made at Banff, where the party lunched at the finely situated hotel of the railway company; and at Laggan, where conveyances were in waiting for a drive to Lake Louise. On September 6 a stop was made at Glacier, in the Selkirk Range, and the glacier and other points of interest were visited on foot.

Vancouver was reached on the morning of September 7, and the party immediately embarked on the steamer for Victoria. Here a reception and conversazione were given in the Parliament Buildings by the Provincial Government, assisted by the Natural History Society. On the following

day excursions were made to various points of interest in the vicinity of the city, including the Naval Dockyard at Esquimalt. A party of biologists visited the biological station at Nanaimo.

The party returned to Vancouver on Wednesday evening, September 8. No formal reception was arranged, but a lecture was delivered in the City Hall by Sir William White on 'Naval Affairs.' On Thursday morning, September 9, facilities were provided for visiting Stanley Park, with its giant pine-trees, and other points of interest in the city and vicinity.

The party left Vancouver east-bound on Thursday evening, and travelled without a break to Strathcona, Alberta, having diverged from the main line at Calgary. At Strathcona, which was reached on Saturday morning, September 11, the special train was handed over by the officials of the Canadian Pacific Railway to those of the Canadian Northern. Mr. Brodie received the thanks of the party for his attention, and he and Mr. Trapp were subsequently made the recipients of presentations on its behalf.

Street cars conveyed the party from Strathcona across the North Saskatchewan River to Edmonton, where some of the chief buildings were inspected. Luncheon was provided, and his Worship the Mayor (Mr. Robert Lee) and Mr. J. A. McDougall, M.P.P., addressed a welcome to the visitors. The President, his Worship the Mayor of Winnipeg (Mr. Sanford Evans), Sir William White, and Sir Joseph Larmor replied. Subsequently the party embarked on a steamer on the North Saskatchewan, and was enabled to inspect the method of gold-washing carried on in that river, and the coal-mining operations on its banks.

Edmonton was left in the evening, and the special train was conveyed over the Canadian Northern Railway to Winnipeg, which was reached on Monday morning, September 13, after a journey of 3,303 miles.

On their return to Winnipeg Members heard with deep regret of the sudden death of Principal D. W. McDermid, who, as Vice-Chairman of the Local Executive Committee, had contributed much to the success of the Meeting, and in particular of the Western excursion, in connection with which he had previously travelled over a great part of the route, making or confirming the necessary arrangements. A wreath was sent to his relatives on behalf of the Association.

INDEX.

References to reports and papers printed in extenso *are given in Italics.*
*An asterisk * indicates that the title only of the communication is given.*
The mark † indicates the same, but that a reference is given to the Journal or Newspaper where the paper is published in extenso.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Life Members (since 1845), and all Annual Members who have not intermitted their Subscription, receive gratis all Reports published after the date of their Membership. Any other volume they require may be obtained on application at the Office of the Association, Burlington House, Piccadilly, London, W., at the following prices: Reports for 1831 to 1874 (*of which more than* 15 *copies remain*), at 2*s.* 6*d.* per volume; after that date, at two-thirds of the Publication Price. A few sets, from 1831 to 1874 inclusive, may also be obtained at £10 per set.

Associates for the Meeting in 1909 may obtain the Volume for the Year at two-thirds of the Publication Price.

REPORT OF THE SEVENTY-EIGHTH MEETING, at Dublin, September 1908, *Published at* £1 4*s.*

CONTENTS.

Publications on Sale at the Office of the Association.

Lithographed Signatures of the Members who met at Cambridge in 1833, with the Proceedings of the Public Meetings, 4to, 4*s.*

Index to the Reports, 1831–1860, 12*s.* (carriage included).

Index to the Reports, 1861–1890, 15*s.* (carriage, 4*d.*).

Lalande's Catalogue of Stars, £1 1*s.*

Rules of Zoological Nomenclature, 1*s.*

On the Regulation of Wages by means of Lists in the Cotton Industry:—Spinning, 2*s.*; Weaving, 1*s.*

Report on the best means for promoting Scientific Education in Schools, 1867, 6*d.*

Report on Electrolysis, 1886, 1*s.*; 1887, 6*d.*; 1888, 6*d.*

Second Report on the present Methods of teaching Chemistry, 1889, 6*d.*

Fifth to Twelfth Reports on the North-Western Tribes of Canada, 1889, 1*s.*; 1890, 2*s.* 6*d.*; 1891, 1*s.*; 1892, 1*s.*; 1894, 6*d.*; 1895, 1*s.* 6*d.*; 1896, 6*d.*; 1898, 1*s.* 6*d.*

Discussion on the Theory of Solution, 1890, 6*d.*

Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements, 1892, 6*d.*; 1893, 6*d.*; 1894, 1*s.*; 1895, 6*d.*; 1899, 6*d.*; 1903, 6*d.*; 1904, 6*d.*; 1905, 6*d.*; 1906, 6*d.*; 1907, 6*d.*; 1908, 6*d.*; 1909, 3*d.*

Second Report on the Development of Graphic Methods in Mechanical Science, 1892, 1*s.*

Report on the Ethnographical Survey of the United Kingdom, 1893, 6*d.*; 1894, 6*d.*

The Action of Magnetism on Light, by J. Larmor, F.R.S., 1893, 1*s.*

Report on the Character of the High-level Shell-bearing Deposits at Clava, Chapelhall, and other Localities, 1893, 6*d.*

Report on the Present State of our Knowledge of Electrolysis and Electro-chemistry, 1893, 6*d.*

Report on the Present State of our Knowledge of Thermodynamics, Part II., by G. H. Bryan; with an Appendix by Prof. L. Boltzmann, 1894, 1*s.*

Report on Planimeters, by Prof. O. Henrici, F.R.S., 1894, 1*s.*

Discussion on Agriculture and Science, Ipswich, 1895, 3*d.*

Fourth Report on the Erosion of the Sea Coasts of England and Wales, 1895, 9*d.*

Second Report on a Gauge for Small Screws, 1884, reprinted 1895, 6*d.*

Report on giving practical effect to the Introduction of the British Association Screw Gauge, 1896, 6*d.*; 1901, 6*d.*; 1903, 6*d.*

Report on Proposed Modification of the Thread of the B.A. Screw, 1900, 6*d.*

Digest of Observations on the Migration of Birds, made at Lighthouses, by W. Eagle Clarke, 1896, 6*d.*

Report on the Migratory Habits of the Song-thrush and the White Wagtail, by W. Eagle Clarke, 1900, 6*d.*

Report on the Migratory Habits of the Skylark and the Swallow, by W. Eagle Clarke, 1901, 6*d.*

Report on the Migratory Habits of the Fieldfare and the Lapwing, by W. Eagle Clarke, 1902, 6*d.*

Report on the Migratory Habits of the Starling and the Rook, by W. Eagle Clarke, 1903, 6*d.*

Report on Tables of the Bessel Functions, 1896, 1*s.*

Report on the Comparison of Magnetic Instruments, 1896, 4*d.*

Report on the Position of Geography in the Educational System of the Country, 1897, 6*d.*

Report of the International Conference on Terrestrial Magnetism and Atmospheric Electricity, 1898, 6*d.*

Report on the Bibliography of Spectroscopy in continuation of 1894 Report, 1898, 1*s.* 6*d.*; 1901, 1*s.* 6*d.*

Report on Wave-lengths, 1899, 1*s.*; 1900, with Index to Tables from 1884 to 1900, 1*s.*; 1901, 1*s.*

Tables of F (r, ν) and H (r, ν) Functions, 1899, 1*s.*

Report on the Ethnological Survey of Canada, 1899, 1*s.* 6*d.*; 1900, 1*s.* 6*d.*; 1902, 1*s.*

Report on Seismology, 1900, 1*s.*; 1901, 1*s.*; 1902, 1*s.*; 1903, 1*s.*; 1904, 1*s.*; 1905, 1*s.*; 1906, 6*d.*; 1907, 6*d.*; 1908, 1*s.*; 1909, 1*s.*

Report on the Chemical Compounds contained in Alloys, by F. H. Neville, F.R.S., 1900, 6*d.*

The Constitution of Camphor, by A. Lapworth, D.Sc., 1900, 1*s.*

Report on Future Dealings in Raw Produce, 1900, 6*d.*

Note sur l'Unité de Pression, par le Dr. C. E. Guillaume, 1901, 3*d.*

Note on the Variation of the Specific Heat of Water, by Prof. H. L. Callendar, 1901, 4*d.*

Report on Absorption Spectra and Chemical Constitution of Organic Substances, 1901, 1*s.*

Report on the Structure of Crystals, 1901, 1*s.*

The Relative Progress of the Coal-tar Industry in England and Germany during the past Fifteen Years, by Arthur G. Green, 1901, 6*d.*

The Methods for the Determination of Hydrolytic Dissociation of Salt Solutions, by R. C. Farmer, 1901, 6*d.*

The Application of the Equilibrium Law to the Separation of Crystals from Complex Solutions and to the Formation of Oceanic Salt Deposits, by Dr. E. Frankland Armstrong, 1901, 1*s.*

Report on the Resistance of Road Vehicles to Traction, 1901, 3*d.*

The Influence of the Universities on School Education, by the Right Rev. John Percival, D.D., Lord Bishop of Hereford, 1901, 3*d.*

Report on Life-zones in the British Carboniferous Rocks, 1901, 6*d.*; 1902, 6*d.*; 1904, 6*d.*

Our Present Knowledge of Aromatic Diazo-compounds, by Dr. Gilbert Thomas Morgan, 1902, 6*d.*

Report on the Teaching of Elementary Mathematics, 1902, 3*d.*

Report on Women's Labour, 1903, 6*d.*

Report on the Teaching of Botany in Schools, 1903, 3*d.*

Report on the Changes in the Sea Coast, 1903, 1*s.*

Report on the Accuracy and Comparability of British and Foreign Statistics of International Trade, 1904, 6*d.*

Report on Anthropometric Investigation in the British Isles, 1906, 1*s.*; 1907, 3*d.*

The Present Position of the Chemistry of Rubber, by S. S. Pickles, 1906, 6*d.*

The Present Position of the Chemistry of Gums, by H. Robinson, 1906, 3*d.*

Standardisation in British Engineering Practice, by Sir John Wolfe-Barry, K.C.B., 1906, 3*d.*

Melanism in Yorkshire Lepidoptera, by G. T. Porritt, 1906, 6*d.*

Preliminary Report on the Magnetic Survey of South Africa, 1906, 3*d.*

Report on the Curricula of Secondary Schools, 1907, 3*d.*

Report on the Sequence of Studies in the Science Section of the Curriculum of Secondary Schools, 1908, 3*d.*

The Development of Wheat Culture in North America, by Professor A. P. Brigham, 1909, 3*d.*

On Threefold Emission Spectra of Solid Aromatic Compounds, by Prof. E. Goldstein, 1909, 3*d.*

Second Report on the Investigation of Gaseous Explosions, with special reference to Temperature, 1909, 6*d.*

The President's Address, and Sectional Addresses, for 1889, 1890, 1891, 1892, 1893, 1895, 1896, 1899, 1900, 1901, 1902, 1909, each 1*s.*

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE

1909

LIST OF MEMBERS

OFFICERS AND COUNCIL

AND

INSTITUTIONS RECEIVING THE REPORT

CORRECTED TO JANUARY 1, 1910

LONDON:
BURLINGTON HOUSE, PICCADILLY, W.

OFFICERS AND COUNCIL, 1909–1910.

PATRON.

HIS MAJESTY THE KING.

PRESIDENT.

PROFESSOR SIR J. J. THOMSON, M.A., Sc.D., D.Sc., F.R.S.

VICE-PRESIDENTS.

The Right Hon. LORD STRATHCONA AND MOUNT ROYAL, G.C.M.G., G.C.V.O., LL.D., High Commissioner in London for the Dominion of Canada.
The Right Hon. Sir WILFRID LAURIER, G.C.M.G., P.C., D.L., Prime Minister and President of Privy Council.
The Hon. Sir DANIEL HUNTER MCMILLAN, K.C.M.G., Lieutenant-Governor of Manitoba.
The Hon. RODMOND PALEN ROBLIN, Premier of Manitoba.
The Hon. AMEDEE E. FORGET, Lieutenant-Governor of Saskatchewan.
The Hon. WALTER SCOTT, Premier of Saskatchewan.
The Hon. GEORGE H. V. BULYEA, Lieutenant-Governor of Alberta.
The Hon. ALEX. C. RUTHERFORD, B.A., LL.D., Premier of Alberta.
The Hon. JAMES DUNSMUIR, Lieutenant-Governor of British Columbia.
The Hon. RICHARD MCBRIDE, LL.B., K.C., Premier of British Columbia.

PRESIDENT ELECT.

Rev. Professor T. G. BONNEY, Sc.D., LL.D., F.R.S.

VICE-PRESIDENTS ELECT.

The Right Hon. the Lord Mayor of Sheffield, The EARL FITZWILLIAM, D.S.O.
The Master Cutler of Sheffield, HERBERT BARBER.
His Grace the LORD ARCHBISHOP OF YORK.
His Grace the DUKE OF NORFOLK, E.M., K.G., G.C.V.O., Litt.D., Chancellor of Sheffield University.
The Right Hon. the EARL OF HAREWOOD, K.C.V.O., Lord-Lieutenant of the West Riding of Yorkshire.
Alderman GEORGE FRANKLIN, Litt.D., Pro-Chancellor of Sheffield University.
Sir CHARLES ELIOT, K.C.M.G., C.B., Vice-Chancellor of Sheffield University.
Alderman H. K. STEPHENSON, Deputy Lord Mayor of Sheffield
The Right Rev. J. N. QUIRK, D.D., Lord Bishop of Sheffield.
A. J. HOBSON, President of the Sheffield Chamber of Commerce.
Alderman Sir WILLIAM CLEGG, J.P., Chairman of the Sheffield Education Committee.
Colonel HERBERT HUGHES, C.M.G.
Professor W. M. HICKS, Sc.D., F.R.S.
Rev. E. H. TITCHMARSH, M.A., President of the Sheffield Free Church Council.

GENERAL TREASURER.

Professor JOHN PERRY, D.Sc., LL.D., F.R.S.

GENERAL SECRETARIES.

Major P. A. MACMAHON, R.A., D.Sc., F.R.S. | Professor W. A. HERDMAN, D.Sc., F.R.S.

ASSISTANT SECRETARY.

O. J. R. HOWARTH, M.A., Burlington House, London, W.

CHIEF CLERK AND ASSISTANT TREASURER.

H. C. STEWARDSON, Burlington House, London, W.

LOCAL TREASURER FOR THE MEETING AT SHEFFIELD.

Alderman H. K. STEPHENSON.

LOCAL SECRETARIES FOR THE MEETING AT SHEFFIELD.

R. M. PRESCOTT. | W. M. GIBBONS, M.A.

ORDINARY MEMBERS OF THE COUNCIL.

ABNEY, Sir W., K.C.B., F.R.S.	HALL, A. D., F.R.S.
ANDERSON, TEMPEST, M.D., D.Sc.	HARTLAND, E. SIDNEY, F.S.A.
ARMSTRONG, Professor H. E., F.R.S.	HOGARTH, D. G., M.A.
BERKELEY, Rt. Hon. the EARL OF, F.R.S.	MITCHELL, Dr. P. CHALMERS, F.R.S.
BOWLEY, A. L., M.A.	MYRES, Professor J. L., M.A.
BRABROOK, Sir EDWARD, C.B.	POULTON, Professor E. B., F.R.S.
BROWN, Dr. HORACE T., F.R.S.	PRAIN, Lieut.-Colonel D., C.I.E., F.R.S.
BRUNTON, Sir LAUDER, Bart., F.R.S.	SHERRINGTON, Professor C. S., F.R.S.
CLOSE, Colonel C. F., R.E., C.M.G.	SHIPLEY, Dr. A. E., F.R.S.
CRAIGIE, Major P. G., C.B.	TEALL, J. J. H., F.R.S.
DYSON, Professor F. W., F.R.S.	TUTTON, Dr. A. E. H., F.R.S.
GLAZEBROOK, Dr. R. T., F.R.S.	WOLFE-BARRY, Sir JOHN, K.C.B., F.R.S.

WOODWARD, Dr. A. SMITH, F.R.S.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past-Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

TRUSTEES (PERMANENT).

The Right Hon. Lord AVEBURY, D.C.L., LL.D., F.R.S., F.L.S.
The Right Hon. Lord RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S.
Sir ARTHUR W. RÜCKER, M.A., D.Sc., LL.D., F.R.S.

PAST PRESIDENTS OF THE ASSOCIATION.

Sir Joseph D. Hooker, G.C.S.I.	Sir A. Geikie, K.C.B., Pres. R.S.	Sir Norman Lockyer, K.C.B., F.R.S
Lord Avebury, D.C.L., F.R.S.	Lord Lister, D.C.L., F.R.S.	Arthur J. Balfour, D.C.L., F.R.S.
Lord Rayleigh, D.C.L., F.R.S.	Sir William Crookes, F.R.S.	Sir George Darwin, K.C.B., F.R.S.
Sir H. E. Roscoe, D.C.L., F.R.S.	Sir W. Turner, K.C.B., F.R.S.	Sir E. Ray Lankester, K.C.B., F.R.S.
Sir William Huggins, K.C.B., F.R.S.	Sir A. W. Rücker, D.Sc., F.R.S.	Sir David Gill, K.C.B., F.R.S.
	Sir James Dewar, LL.D., F.R.S.	Dr. Francis Darwin, F.R.S.

PAST GENERAL OFFICERS OF THE ASSOCIATION.

Sir F. Galton, D.C.L., F.R.S.	A. Vernon Harcourt, F.R.S.	Dr. D. H. Scott, M.A., F.R.S.
P. L. Sclater, Ph.D., F.R.S.	Sir A. W. Rücker, D.Sc., F.R.S.	Dr. G. Carey Foster, F.R.S.
Prof. T. G. Bonney, Sc.D., F.R.S.	Prof. E. A. Schäfer, F.R.S.	Dr. J. G. Garson.

AUDITORS.

Sir Edward Brabrook, C.B.	Professor H. McLeod, F.R.S.

LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1909.

* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members, elected before 1845, not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Assistant Secretary, Burlington House, London, W.

Year of Election.

1905. *à Ababrelton, Robert, F.R.G.S. P.O. Box 322, Pietermaritzburg, Natal.
1887. *ABBE, Professor CLEVELAND. Local Office, U.S.A. Weather Bureau, Baltimore, U.S.A.
1881. *Abbott, R. T. G. Whitley House, Malton.
1885. *ABERDEEN, The Earl of, G.C.M.G., LL.D. Haddo House, Aberdeen.
1885. ‡Aberdeen, The Countess of. Haddo House, Aberdeen.
1873. *ABNEY, Captain Sir W. DE W., K.C.B., D.C.L., F.R.S., F.R.A.S. (Pres. A, 1889; Pres. L, 1903; Council, 1884–89, 1902–05, 1906– .) Measham Hall, Leicestershire.
1905. ‡Abrahamson, Louis. Civil Service Club, Cape Town.
1905. §Aburrow, Charles. P.O. Box 534, Johannesburg.
1882. **Acland, Alfred Dyke.* 38 *Pont-street, Chelsea, S.W.*
1869. ‡Acland, Sir C. T. Dyke, Bart., M.A. Killerton, Exeter.
1877. *Acland, Captain Francis E. Dyke, R.A. Walwood, Banstead, Surrey.
1894. *Acland, Henry Dyke, F.G.S. Lamorva, Falmouth.
1877. *Acland, Theodore Dyke, M.D. 19 Bryanston-square, W.
1904. §Acton, T. A. 3 Grove-road, Wrexham.
1898. ‡ACWORTH, W. M., M.A. (Pres. F, 1908.) The Albany, W.

Year Election

1901. ‡Adam, J. Miller. 15 Walmer-crescent, Glasgow.
1887. ‡ADAMI, J. G., M.A., M.D., F.R.S., Professor of Pathology in McGill University, Montreal, Canada.
1901. §Adams, John, M.A., Professor of Education in the University of London. 23 Tanza-road, Hampstead, N.W.
1904. ‡Adams, W. G. S., M.A. Department of Agriculture, Upper Merrion-street, Dublin.
1869. *ADAMS, WILLIAM GRYLLS, M.A., D.Sc., F.R.S., F.G.S., F.C.P.S. (Pres. A, 1880 ; Council, 1878-85.) Heathfield, Broadstone, Dorset.
1908. §Adamson, R. Stephen. Emmanuel College, Cambridge.
1898. ‡Addison, William L. T. Byng Inlet, Ontario, Canada.
1890. ‡ADENEY, W. E., D.Sc., F.C.S. Royal University of Ireland, Earlsfort-terrace, Dublin.
1899. *Adie, R. H., M.A., B.Sc. 136 Huntingdon-road, Cambridge.
1908. §Adkin, Robert. 4 Lingard's-road, Lewisham, S.E.
1905. ‡Adle, Henry. P.O. Box 1059, Johannesburg.
1908. *Agar, W. E., M.A. Natural History Department, The University, Glasgow.
1902. ‡Agnew, Samuel, M.D. Bengal-place, Lurgan.
1909. §Aikins, J. Somerset. 426 Assiniboine-avenue, Winnipeg, Canada.
1906. §Aikman, J. A. 6 Glencairn-crescent, Edinburgh.
1871. *Ainsworth, John Stirling. Harecroft, Gosforth, Cumberland.
1909. *AIRD, JOHN. Canadian Bank of Commerce, Winnipeg, Canada.
1890. *AIREDALE, Lord. Gledhow Hall, Leeds.
1895. *Airy, Hubert, M.D. Stoke House, Woodbridge, Suffolk.
1891. *Aisbitt, M. W. Mountstuart-square, Cardiff.
1871. §AITKEN, JOHN, LL.D., F.R.S., F.R.S.E. Ardenlea, Falkirk, N.B.
1901. ‡Aitken, Thomas, M.Inst.C.E. County Buildings, Cupar-Fife.
1884. *Alabaster, H. Milton, Grange-road, Sutton, Surrey.
1886. *Albright, G. S. Broomsberrow Place, Ledbury.
1905. ‡Albright, Miss. Finstal Farm, Finstal, Bromsgrove, Worcestershire.
1907. §Alcock, N. H., M.D., D.Sc. 22 Downshire-hill, Hampstead, N.W.
1900. *Aldren, Francis J., M.A. The Lizans, Malvern Link.
1896. §Aldridge, J. G. W., Assoc.M.Inst.C.E. 39 Victoria-street, Westminster, S.W.
1905. *Alexander, J. Abercromby, F.S.A. 24 Lawn-crescent, Kew.
1888. *Alexander, Patrick Y. 82 Victoria-street, S.W.
1891. *Alford, Charles J., F.G.S. Hôtel Angleterre, Vevey, Switzerland.
1883. ‡Alger, W. H. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.
1901. *Allan, James A. Westerton, Milngavie.
1904. *Allcock, William Burt. Emmanuel College, Cambridge.
1879. *Allen, Rev. A. J. C. 34 Lensfield-road, Cambridge.
1898. §ALLEN, Dr. E. J. The Laboratory, Citadel Hill, Plymouth.
1888. ‡ALLEN, F. J., M.A. 108 Mawson-road, Cambridge.
1907. *Allorge, M. M., L. ès Sc., F.G.S. University Museum, Oxford.
1882. *Alverstone, The Right Hon. Lord, G.C.M.G., LL.D., F.R.S. Hornton Lodge, Hornton-street, Kensington, W.
1887. ‡Alward, G. L. 11 Hamilton-street, Grimsby, Yorkshire.
1883. §Amery, John Sparke. Druid, Ashburton, Devon.
1884. ‡AMI, HENRY, M.A., D.Sc., F.G.S. Geological Survey, Ottawa, Canada.
1909. §Ami, H. M., M.D. Ottawa, Canada.
1905. ‡Anderson, A. J., M.A., M.B. The Residency, Portswood-road, Green Point, Cape Colony.

Year of Election.

1905. *Anderson, C. L. P.O. Box 2162, Johannesburg.
1908. ‡Anderson, Edgar. Glenavon, Merrion-road, Dublin.
1885. *ANDERSON, HUGH KERR, M.A., M.D., F.R.S. Caius College, Cambridge.
1901. *Anderson, James. Ravelston, Kelvinside, Glasgow.
1892. ‡Anderson, Joseph, LL.D. 8 Great King-street, Edinburgh.
1899. *Anderson, Miss Mary Kerr. 13 Napier-road, Edinburgh.
1888. *Anderson, R. Bruce. 5 Westminster-chambers, S.W.
1887. ‡ANDERSON, Professor R. J., M.D., F.L.S. Queen's College, and Atlantic Lodge, Salthill, Galway.
1905. ‡Anderson, T. J. P.O. Box 173, Cape Town.
1880. *ANDERSON, TEMPEST, M.D., D.Sc., F.G.S. (Council, 1907– ; Local Sec. 1881.) 17 Stonegate, York.
1902. *Anderson, Thomas. Embleton, Osborne Park, Belfast.
1901. *Anderson, Dr. W. Carrick. 8 Windsor-quadrant, Glasgow.
1908 ‡Anderson, William. Glenavon, Merrion-road, Dublin.
1907. ‡Andrews, A. W. Adela-avenue, West Barnes-lane, New Malden, Surrey.
1909. §Andrews, Alfred J., Care of Messrs. Andrews, Andrews, & Co., Winnipeg, Canada.
1895. ‡Andrews, Charles W., B.A., D.Sc., F.R.S. British Museum (Natural History), S.W.
1909. §Andrews, G. W. 433 Main-street, Winnipeg, Canada.
1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
1886. §Andrews, William, F.G.S. Steeple Croft, Coventry.
1877. §ANGELL, JOHN, F.C.S., F.I.C. 6 Beacons-field, Derby-road, Withington, Manchester.
1900. ‡Annandale, Nelson. 34 Charlotte-square, Edinburgh.
1896. ‡Annett, R. C. F., Assoc.Inst.C.E. 4 Buckingham-avenue, Sefton Park, Liverpool.
1886. ‡Ansell, Joseph. 27 Bennett's-hill, Birmingham.
1890. §Antrobus, J. Coutts. Eaton Hall, Congleton.
1901. ‡Arakawa, Minozi. Japanese Consulate, 84 Bishopsgate-street Within, E.C.
1900. ‡Arber, E. A. Newell, M.A., F.L.S. Trinity College, Cambridge.
1894. ‡Archibald, A. Holmer, Court-road, Tunbridge Wells.
1884. *Archibald, E. Douglas. Constitutional Club, W.C.
1909. §Archibald, E. H. Bowne Hall of Chemistry, Syracuse University, Syracuse, New York, U.S.A.
1909. §Archibald, H. Care of Messrs. Machray, Sharpe, & Dennistoun, Bank of Ottawa Chambers, Winnipeg, Canada.
1883. *Armistead, William. Hillcrest, Oaken, Wolverhampton.
1908. ‡Armstrong, E. C. R., M.R.I.A., F.R.G.S. Cyprus, Eglinton-road, Dublin.
1903. *ARMSTRONG, E. FRANKLAND, D.Sc., Ph.D. 98 London-road, Reading.
1873. *ARMSTRONG, HENRY E., Ph.D., LL.D., F.R.S. (Pres. B, 1885, 1909; Pres. L, 1902; Council, 1899–1905, 1909–), Professor of Chemistry in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 55 Granville-park, Lewisham, S.E.
1909. §Armstrong, Hon. Hugh. Parliament Buildings, Kennedy-street, Winnipeg, Canada.
1905. ‡Armstrong, John. Kamfersdam Mine, near Kimberley, Cape Colony.
1905. §ARNOLD, J. O., Professor of Metallurgy in the University of Sheffield.

Year of Election.

1893. *ARNOLD-BEMROSE, H. H., Sc.D., F.G.S. Ash Tree House, Osmaston-road, Derby.
1904. ‡Arunachalam, P. Ceylon Civil Service, Colombo, Ceylon.
1870. *Ash, Dr. T. Linnington. Penroses, Holsworthy, North Devon.
1903. *Ashby, Thomas. The British School, Rome.
1909. §Ashdown, J. H. 337 Broadway, Winnipeg, Canada.
1907. ‡ASHLEY, W. J., M.A. (Pres. F, 1907), Professor of Commerce in the University of Birmingham. 3 Yateley-road, Edgbaston, Birmingham.
Ashworth, Henry. Turton, near Bolton.
1903. *Ashworth, J. H., D.Sc. 4 Cluny-terrace, Edinburgh.
1890. ‡Ashworth, J. Reginald, D.Sc. 105 Freehold-street, Rochdale.
1905. ‡Askew, T. A. Main-road, Claremont, Cape Colony.
1875. *Aspland, W. Gaskell. 50 Park Hill-road, N.W.
1896. *Assheton, Richard, M.A., F.L.S. Grantchester, Cambridge.
1905. ‡Assheton, Mrs. Grantchester, Cambridge.
1908. §Astley, Rev. H. J. Dukinfield, M.A. East Rudham Vicarage, King's Lynn.
1903. ‡Atchison, Arthur F. T., B.Sc. Royal Engineering College, Cooper's Hill, Staines.
1887. §Atkinson, Rev. C. Chetwynd, D.D. Ingestre, Ashton-on-Mersey.
1898. *Atkinson, E. Cuthbert. 5 Pembroke-vale, Clifton, Bristol.
1894. *Atkinson, Harold W., M.A. West View, Eastbury-avenue, Northwood, Middlesex.
1906. ‡Atkinson, J. J. Cosgrove Priory, Stony Stratford.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1907. ‡Atkinson, Robert E. Morland-avenue, Knighton, Leicester.
1881. ‡ATKINSON, ROBERT WILLIAM, F.C.S. (Local Sec. 1891.) 44 Loudoun-square, Cardiff.
1863. *ATTFIELD, J., M.A., Ph.D., F.R.S., F.C.S. Ashlands, Watford, Herts.
1906. §AUDEN, Dr. G. A. The Education Office, Edmund-street, Birmingham.
1907. §Auden, H. A., D.Sc. Westwood, Grassendale, Liverpool.
1903. ‡AUSTIN, CHARLES E. 37 Cambridge-road, Southport.
1853. *AVEBURY, The Right Hon. Lord, D.C.L., F.R.S. (PRESIDENT, 1881; TRUSTEE, 1872– ; Pres. D, 1872; Council, 1865–71.) High Elms, Farnborough, Kent.
1909. §Axtell, S. W. Stobart Block, Winnipeg, Canada.

1883. *Bach-Gladstone, Madame Henri. 147 Rue de Grenelle, Paris.
1906. ‡Backhouse, James. Daleside, Scarborough.
1883. *Backhouse, W. A. St. John's, Wolsingham, R.S.O., Durham.
1887. *Bacon, Thomas Walter. Ramsden Hall, Billericay, Essex.
1903. ‡Baden-Powell, Major B. 22 Prince's-gate, S.W.
1907. §Badgley, Colonel W. F., Assoc.Inst.C.E., F.R.G.S. Verecroft, Devizes.
1908. *Bagnall, Richard Siddoway. The Groves, Winlaton, Co. Durham.
1905. ‡Baikie, Robert. P.O. Box 36, Pretoria, South Africa.
1883. ‡Baildon, Dr. 42 Hoghton-street, Southport.
1883. *Bailey, Charles, M.Sc., F.L.S. Haymesgarth, Cleeve Hill S.O., Gloucestershire.
1893. ‡BAILEY, Colonel F., F.R.G.S. 7 Drummond-place, Edinburgh.
1887. *Bailey, G. H., D.Sc., Ph.D. Marple Cottage, Marple, Cheshire.
1905. *Bailey, Harry Percy. 22 Clarendon-road, Margate.
1905. §Bailey, Right Hon. W. F., C.B. Land Commission, Dublin.
1894. *BAILY, FRANCIS GIBSON, M.A. Newbury, Colinton, Midlothian.

Year of Election.

1878. ‡BAILY, WALTER. 4 Roslyn-hill, Hampstead, N.W.
1905. *Baker, Sir Augustine. 56 Merrion-square, Dublin.
1886. §Baker, Harry, F.I.C. Epworth House, Moughland-lane, Runcorn.
1907. ‡Baldwin, Walter. 5 St. Alban's-street, Rochdale.
1904. ‡BALFOUR, The Right Hon. A. J., D.C.L., LL.D., M.P., F.R.S., Chancellor of the University of Edinburgh. (PRESIDENT, 1904.) Whittinghame, Prestonkirk, N.B.
1894. ‡BALFOUR, HENRY, M.A. (Pres. H, 1904.) Langley Lodge, Headington Hill, Oxford.
1905. ‡Balfour, Mrs. H. Langley Lodge, Headington Hill, Oxford.
1875. ‡BALFOUR, ISAAC BAYLEY, M.A., D.Sc., M.D., F.R.S., F.R.S.E., F.L.S. (Pres. D, 1894; K, 1901), Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1905. ‡Balfour, Mrs. J. Dawyck, Stobo, N.B.
1905. ‡Balfour, Lewis. 11 Norham-gardens, Oxford.
1905. ‡Balfour, Miss Vera B. Dawyck, Stobo, N.B.
1878. *Ball, Sir Charles Bent, M.D., Regius Professor of Surgery in the University of Dublin. 24 Merrion-square, Dublin.
1866. *BALL, Sir ROBERT STAWELL, LL.D., F.R.S., F.R.A.S. (Pres. A, 1887; Council, 1884–90, 1892–94; Local Sec. 1878), Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1908. ‡Ball, T. Elrington. 6 Wilton-place, Dublin.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1905. ‡Ballantine, Rev. T. R. Tirmochree, Bloomfield, Belfast.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1890. ‡Bamford, Professor Harry, M.Sc. 30 Falkland-mansions, Glasgow.
1909. §Bampfield, Mrs. E. 303 Donald-street, Winnipeg, Canada.
1899. §Bampton, Mrs. 42 Marine-parade, Dover.
1905. §Banks, Miss Margaret Pierrepont. 10 Regent-terrace, Edinburgh.
1898. ‡Bannerman, W. Bruce, F.S.A. The Lindens, Sydenham-road, Croydon.
1909. §Baragar, Charles A. University of Manitoba, Winnipeg, Canada.
1910. §Barber, Miss Mary. 25 Holland-street, Kensington, W.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1887. *Barclay, Robert. Sedgley New Hall, Prestwich, Manchester.
1902. ‡Barcroft, H., D.L. The Glen, Newry, Co. Down.
1902. ‡Barcroft, Joseph, M.A., B.Sc. King's College, Cambridge.
1904. §Barker, B. T. P., M.A. Fenswood, Long Ashton, Bristol.
1906. *Barker, Geoffrey Palgrave. Henstead Hall, near Wrentham, Suffolk.
1899. §Barker, John H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
1882. *Barker, Miss J. M. Care of Mrs. Plummer, Prior's-terrace, Tynemouth.
1898. ‡Barker, W. R. 106 Redland-road, Bristol.
1909. §Barlow, Lieut.-Colonel G. N. H. Care of Messrs. Cox & Co., 16 Charing Cross, S.W.
1889. ‡Barlow, H. W. L., M.A., M.B., F.C.S. The Park Hospital, Hither Green, S.E.
1883. ‡Barlow, J. J. 84 Cambridge-road, Southport.
1885. *BARLOW, WILLIAM, F.R.S., F.G.S. The Red House, Great Stanmore.

Year of Election.

1905. §Barnard, Miss Annie T., M.D., B.Sc. 32 Chenies-street-chambers, Gower-street, W.C.
1902. §Barnard, J. E. Park View, Brondesbury Park, N.W.
1881. ‡Barnard, William, LL.B. 3 New-court, Lincoln's Inn, W.C.
1904. ‡Barnes, Rev. E. W., M.A., F.R.A.S. Trinity College, Cambridge.
1907. §Barnes, Professor H. T. McGill University, Montreal, Canada.
1909. *Barnett, Miss Edith A. Holm Leas, Worthing.
1881. ‡BARR, ARCHIBALD, D.Sc., M.Inst.C.E., Professor of Civil Engineering in the University, Glasgow.
1902. *Barr, Mark. Gloucester-mansions, Harrington-gardens, S.W.
1904. ‡Barrett, Arthur. 6 Mortimer-road, Cambridge.
1872. *BARRETT, W. F., F.R.S., F.R.S.E., M.R.I.A., Professor of Physics in the Royal College of Science, Dublin. 6 De Vesci-terrace, Kingstown, Co. Dublin.
1874. *BARRINGTON, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington-Ward, Rev. Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1893. *BARROW, GEORGE, F.G.S. 28 Jermyn-street, S.W.
1896. §Barrowman, James. Staneacre, Hamilton, N.B.
1908. ‡Barry, Gerald H. Wiglin Glebe, Carlow, Ireland.
1884. *Barstow, Miss Frances A. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.
1892. ‡Bartholomew, John George, F.R.S.E., F.R.G.S. Newington House, Edinburgh.
1858. *Bartholomew, William Hamond, M.Inst.C.E. Ridgeway House, Cumberland-road, Hyde Park, Leeds.
1909. §Bartleet, Arthur M. 138 Hagley-road, Edgbaston, Birmingham.
1909. §Bartlett, C. Bank of Hamilton-building, Winnipeg, Canada.
1893. *Barton, Edwin H., D.Sc., F.R.S.E., Professor of Experimental Physics in University College, Nottingham.
1908. ‡Barton, Rev. Walter John, B.A., F.R.G.S. The College, Winchester.
1904. *Bartrum, C. O., B.Sc. 12 Heath-mansions, Heath-street, Hampstead, N.W.
1845. *Bashforth, Rev. Francis, B.D. Woodhall Spa, Lincoln.
1888. *BASSET, A. B., M.A., F.R.S. Fledborough Hall, Holyport, Berkshire.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *BASSETT, HENRY. 26 Belitha-villas, Barnsbury, N.
1889. ‡BASTABLE, Professor C. F., M.A., F.S.S. (Pres. F, 1894.) 6 Trevelyan-terrace, Rathgar, Co. Dublin.
1871. ‡BASTIAN, H. CHARLTON, M.A., M.D., F.R.S., F.L.S., Emeritus Professor of the Principles and Practice of Medicine in University College, London. 8A Manchester-square, W.
1883. ‡BATEMAN, Sir A. E., K.C.M.G. Woodhouse, Wimbledon Park, S.W.
1907. *Bateman, Harry. The University, Manchester.
1884. ‡BATESON, WILLIAM, M.A., F.R.S. (Pres. D, 1904), Professor of Biology in the University of Cambridge. St. John's College, Cambridge.
1881. *BATHER, FRANCIS ARTHUR, M.A., D.Sc., F.G.S. British Museum (Natural History), S.W.
1906. §Batty, Mrs. Braithwaite. Ye Gabled House, The Parks, Oxford.
1904. ‡Baugh, J. H. Agar. 92 Hatton-garden, E.C.
1909. §Bawlf, Nicholas. Assiniboine-avenue, Winnipeg, Canada.
1905. ‡Baxter, W. Duncan. P.O. Box 103, Cape Town.

Year of Election.

1876. *Baynes, Robert E., M.A. Christ Church, Oxford.
1887. *Baynes, Mrs. R. E. 2 Norham-gardens, Oxford.
1883. *Bazley, Gardner S. Hatherop Castle, Fairford, Gloucestershire.
1905. *Bazley, Miss J. M. A. Kilmorie, Ilsham-drive, Torquay, Devon.
Bazley, Sir Thomas Sebastian, Bart., M.A. Kilmorie, Ilsham-drive, Torquay, Devon.
1909. *Beadnell, H. J. Llewellyn, F.G.S. 51 Warwick-road, Ealing, W.
1889. §Beare, Professor T. Hudson, B.Sc., F.R.S.E., M.Inst.C.E. The University, Edinburgh.
1905. §Beare, Mrs. T. Hudson. 10 Regent-terrace, Edinburgh.
1904. §Beasley, H. C. 25a Prince Alfred-road, Wavertree, Liverpool.
1905. ‡Beattie, Professor J. C., D.Sc., F.R.S.E. South African College, Cape Town.
1900. ‡Beaumont, Professor Roberts, M.I.Mech.E. The University, Leeds.
1861. *Beaumont, Rev. Thomas George. Oakley Lodge, Leamington.
1887. *Beaumont, W. J. The Laboratory, Citadel Hill, Plymouth.
1885. *Beaumont, W. W., M.Inst.C.E. Outer Temple, 222 Strand, W.C.
1887. *Beckett, John Hampden. Corbar Hall, Buxton, Derbyshire.
1904. §Beckit, H. O. Cheney Cottage, Headington, Oxford.
1885. ‡Beddard, Frank E., M.A., F.R.S., F.Z.S., Prosector to the Zoological Society of London, Regent's Park, N.W.
1870. ‡Beddoe, John, M.D., F.R.S. (Council, 1870–75.) The Chantry, Bradford-on-Avon.
1904. *Bedford, T. G., M.A. 13 Warkworth-street, Cambridge.
1891. ‡Bedlington, Richard. Gadlys House, Aberdare.
1878. ‡Bedson, P. Phillips, D.Sc., F.C.S. (Local Sec. 1889), Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.
1901. *Beilby, G. T., LL.D., F.R.S. (Pres. B, 1905.) 11 University-gardens, Glasgow.
1905. ‡Beilby, Hubert. 11 University-gardens, Glasgow.
1891. *Belinfante, L. L., M.Sc., Assist. Sec. G.S. Burlington House, W.
1909. §Bell, C. N. (Local Sec., 1909). 121 Carlton-street, Winnipeg, Canada.
1894. ‡Bell, F. Jeffrey, M.A., F.Z.S. British Museum, S.W.
1900. *Bell, Henry Wilkinson. Beech Cottage, Rawdon, near Leeds.
1870. *Bell, J. Carter, A.R.S.M. The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. 102 Leyland-road, Southport.
1905. ‡Bell, W. H. S. P.O. Box 4284, Johannesburg.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1908. *Bellamy, Frank Arthur, M.A., F.R.A.S. University Observatory, Oxford.
1904. ‡Bellars, A. E. Magdalene College, Cambridge.
1905. ‡Bender, Rev. A. P., M.A. Synagogue House, Cape Town.
1883. *Bennett, Laurence Henry. The Elms, Paignton, South Devon.
1901. ‡Bennett, Professor Peter. 6 Kelvinhaugh-street, Sandyford, Glasgow.
1909. *Bennett, R. B., K.C. Calgary, Alberta, Canada.
1905. §Benson, Arthur H., M.A., F.R.C.S.I. 42 Fitzwilliam-square, Dublin.
1905. §Benson, Mrs. A. H. 42 Fitzwilliam-square, Dublin.
1909. §Benson, Miss C. C. Terralta, Port Hope, Ontario, Canada.
1903. §Benson, D. E. Queenwood, 12 Irton-road, Southport.
1901. *Benson, Miss Margaret J., D.Sc. Royal Holloway College, Egham.
1887. *Benson, Mrs. W. J. Care of Johannesburg Consolidated Investment Co., P.O. Box 590, Johannesburg, Transvaal.

Year of Election.

1893. *Bent, Mrs. Theodore. 13 Great Cumberland-place, W.
1904. ‡Bentley, B. H. The University, Sheffield.
1905. *Bentley, W. C. Rein Wood, Huddersfield.
1908. §Benton, Mrs. Evelyn M. Kingswear, Hale, Altrincham, Cheshire.
1896. *Bergin, William, M.A., Professor of Natural Philosophy in Queen's College, Cork.
1894. §BERKELEY, The Earl of, F.R.S., F.G.S. (Council, 1909–). Foxcombe, Boarshill, near Abingdon.
1905. *BERNACCHI, L. C., F.R.G.S. Pound Farm, Upper Long Ditton, Surrey.
1906. *Bernays, Albert Evan. 3 Priory-road, Kew, Surrey.
1898. §Berridge, Miss C. E. 7 Albert-mansions, Lansdowne-road, Croydon.
1894. §BERRIDGE, DOUGLAS, M.A., F.C.S. The College, Malvern.
1908. *Berridge, Miss Emily M. Dunton Lodge, The Knoll, Beckenham.
1903. *Berry, Arthur J. 5 University-gardens, Glasgow.
1904. §Berry, R. A. West of Scotland Agricultural College, 6 Blythswood-square, Glasgow.
1905. ‡Bertrand, Captain Alfred. Champel, Geneva.
1862. ‡BESANT, WILLIAM HENRY, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1880. *BEVAN, Rev. JAMES OLIVER, M.A., F.S.A., F.G.S. Chillenden Rectory, Dover.
1904. *Bevan, P. V., M.A. Hillside, Egham.
1906. ‡Bevan-Lewis, W., M.D. West Riding Asylum, Wakefield.
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1903. ‡Bickerdike, C. F. 1 Boverney-road, Honor Oak Park, S.E.
1888. *Bidder, George Parker. Savile Club, Piccadilly, W.
1910. §Biddlecombe, A. 50 Grainger-street, Newcastle-on-Tyne.
1904. §BIGG-WITHER, Colonel A. C., F.R.A.S. Tilthams, Godalming, Surrey.
1882. ‡Biggs, C. H. W., F.C.S. Glebe Lodge, Champion-hill, S.E.
1898. ‡Billington, Charles. Heimath, Longport, Staffordshire.
1901. *Bilsland, Sir William, Bart., J.P. 28 Park-circus, Glasgow.
1908. *Bilton, Edward Barnard. Graylands, Wimbledon Common, S.W.
1887. *Bindloss, James B. Elm Bank, Buxton.
1909. §Bingham, Alexander R. 16 Kingsmead-road South, Birkenhead.
1909. §Bingham, Mrs. E. G. 16 Kingsmead-road South, Birkenhead.
1884. *Bingham, Colonel Sir John E., Bart. West Lea, Ranmoor, Sheffield.
1881. ‡BINNIE, Sir ALEXANDER R., M.Inst.C.E., F.G.S. (Pres. G, 1900.) 77 Ladbroke-grove, W.
1887. *Birley, H. K. Penrhyn, Irlams o' th' Height, Manchester.
1904. ‡Bishop, A. W. Edwinstowe, Chaucer-road, Cambridge.
1906. §Bishop, J. L. Inland Revenue Office, York.
1894. ‡Bisset, James, F.R.S.E. 9 Greenhill-park, Edinburgh.
1886. *Bixby, Colonel W. H. 428 Custom House, St. Louis, Mo., U.S.A.
1909. §Black, G. M. 381 Main-street, Winnipeg, Canada.
1909. §Black, W. J., Principal of Manitoba Agricultural College, Winnipeg, Canada.
1901. §Black, W. P. M. 136 Wellington-street, Glasgow.
1903. *BLACKMAN, F. F., M.A., D.Sc., F.R.S. (Pres. K, 1908.) St. John's College, Cambridge.
1908. §Blackman, Professor V. H., M.A., Sc.D. The University, Leeds.
1909. §Blaikie, Leonard, M.A. Civil Service Commission, Burlington-gardens, W.
1902. ‡Blake, Robert F., F.I.C. Queen's College, Belfast.
1900. *Blamires, Joseph. Bradley Lodge, Huddersfield.

Year of Election.

1905. ‡Blamires, Mrs. Bradley Lodge, Huddersfield.
1904. ‡Blanc, Dr. Gian Alberto. Istituto Fisico, Rome.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1887. *Bles, A. J. S. Palm House, Park-lane, Higher Broughton, Manchester.
1887. *Bles, Edward J., M.A., D.Sc. The Mill House, Iffley, Oxford.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1902. ‡Blount, Bertram, F.I.C. 76 & 78 York-street, Westminster, S.W.
1888. ‡Bloxsom, Martin, B.A., M.Inst.C.E. Hazelwood, Crumpsall Green, Manchester.
1909. §Blumfeld, Joseph, M.D. 7 Cavendish-place, W.
Blyth, B. Hall. 135 George-street, Edinburgh.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1900. ‡BODINGTON, Sir NATHAN, Litt.D. The University, Leeds.
1908. §BOEDDICKER, OTTO, Ph.D. Birr Castle Observatory, Birr, Ireland.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1898. §BOLTON, H., F.R.S.E. The Museum, Queen's-road, Bristol.
1894. §BOLTON, JOHN. 15 Cranley-gardens, Muswell Hill, N.
1898. *BONAR, JAMES, M.A., LL.D. (Pres. F, 1898; Council, 1899–1905.) The Mint, Ottawa, Canada.
1909. §Bonar, Thomson, M.D. 114 Via Babuino, Piazza di Spagna, Rome.
1909. §Bond, J. H. R., M.B. 167 Donald-street, Winnipeg, Canada.
1908. ‡Bone, Professor W. A., D.Sc., F.R.S. The University, Leeds.
1871. *BONNEY, Rev. THOMAS GEORGE, Sc.D., LL.D., F.R.S., F.S.A., F.G.S. (PRESIDENT ELECT; SECRETARY, 1881–85; Pres. C, 1886.) 9 Scroope-terrace, Cambridge.
1888. ‡Boon, William. Coventry.
1893. ‡Boot, Sir Jesse. Carlyle House, 18 Burns-street, Nottingham.
1890. *BOOTH, Right Hon. CHARLES, D.Sc., F.R.S., F.S.S. 24 Great Cumberland Place, W.
1883. ‡Booth, James. Hazelhurst, Turton.
1908. §Booth, Robert, J.P. Bartra Hall, Dalkey, Co. Dublin.
1883. ‡Boothroyd, Benjamin. Weston-super-Mare.
1901. *Boothroyd, Herbert E., M.A., B.Sc. Sidney Sussex College, Cambridge.
1882. §BORNS, HENRY, Ph.D., F.C.S. 5 Sutton Court-road, Chiswick, W.
1901. ‡Borradaile, L. A., M.A. Selwyn College, Cambridge.
1876. *BOSANQUET, R. H. M., M.A., F.R.S., F.R.A.S. Castillo Zamora, Realejo-Alto, Teneriffe.
1903. §Bosanquet, Robert C., M.A., Professor of Classical Archæology in the University of Liverpool. Institute of Archæology, 40 Bedford-street, Liverpool.
1896. ‡Bose, Professor J. C., C.I.E., M.A., D.Sc. Calcutta, India.
1881. §BOTHAMLEY, CHARLES H., M.Sc., F.I.C., F.C.S., Education Secretary, Somerset County Council, Weston-super-Mare.
1871. *BOTTOMLEY, JAMES THOMSON, M.A., LL.D., D.Sc., F.R.S., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
1892. *Bottomley, W. B., B.A., Professor of Botany in King's College, W.C.
1909. §Boulenger, C. L. 8 Courtfield-road, S.W.
1905. §BOULENGER, G. A., F.R.S. (Pres. D, 1905.) 8 Courtfield-road, S.W.
1905. §Boulenger, Mrs. 8 Courtfield-road, S.W.
1903. §BOULTON, W. S., B.Sc., F.G.S., Professor of Geology in University College, Cardiff. 26 Arches-road, Penarth.
1883. ‡BOURNE, A. G., D.Sc., F.R.S., F.L.S., Professor of Biology in the Presidency College, Madras.

Year of Election.

1893. *BOURNE, G. C., M.A., D.Sc., F.L.S. (Council, 1903-09 ; Local Sec. 1894), Linacre Professor of Comparative Anatomy in the University of Oxford. Savile House, Mansfield-road, Oxford.

1904. *Bousfield, E. G. P. Clarendon Lodge, Blyth Bridge, Stoke-on-Trent.

1902. ‡Bousfield, Sir William. 20 Hyde Park-gate, W.

1884. ‡BOVEY, HENRY T., M.A., LL.D., F.R.S., M.Inst.C.E., Rector of the Imperial College of Science and Technology, South Kensington, S.W.

1881. *BOWER, F. O., D.Sc., F.R.S., F.R.S.E., F.L.S. (Pres. K, 1898 ; Council, 1900-06), Regius Professor of Botany in the University of Glasgow.

1898. *Bowker, Arthur Frank, F.R.G.S., F.G.S. Whitehill, Wrotham, Kent.

1856. *Bowlby, Miss F. E. 4 South Bailey, Durham.

1908. §Bowles, E. Augustus, M.A., F.L.S. Myddelton House, Waltham Cross, Herts.

1898. §BOWLEY, A. L., M.A. (Pres. F, 1906 ; Council, 1906- .) North-court-avenue, Reading.

1880. ‡Bowly, Christopher. Cirencester.

1887. ‡Bowly, Mrs. Christopher. Cirencester.

1899. *Bowman, Herbert Lister, M.A., D.Sc., F.G.S., Professor of Mineralogy in the University of Oxford. Magdalen College, Oxford.

1899. *Bowman, John Herbert. Greenham Common, Newbury.

1887. §Box, Alfred Marshall. Care of the Lancashire and Yorkshire Bank, Huddersfield.

1895. *BOYCE, Sir RUBERT, M.B., F.R.S., Professor of Pathology in the University of Liverpool.

1901. ‡Boyd, David T. Rhinsdale, Ballieston, Lanark.

1892. ‡BOYS, CHARLES VERNON, F.R.S. (Pres. A, 1903 ; Council, 1893-99, 1905-08.) 66 Victoria-street, S.W.

1905. ‡Boys, Mrs. C. Vernon. 66 Victoria-street. S.W.

1872. *BRABROOK, Sir EDWARD, C.B., F.S.A. (Pres. H, 1898 ; Pres. F, 1903 ; Council, 1903- .) 178 Bedford-hill, Balham, S.W.

1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.

1894. *Braby, Ivon. Helena, Alan-road, Wimbledon, S.W.

1905. ‡Bradford, Wager. P.O. Box 5, Johannesburg.

1893. §Bradley, F. L. Ingleside, Malvern Wells.

1904. *Bradley, Gustav. Council Offices, Goole.

1899. *Bradley, J. W., Assoc.M.Inst.C.E. Westminster City Hall, Charing Cross-road, W.C.

1903. *Bradley, O. Charnock, D.Sc., M.D., F.R.S.E. Royal Veterinary College, Edinburgh.

1892. ‡Bradshaw, W. Carisbrooke House, The Park, Nottingham.

1863. ‡BRADY, GEORGE S., M.D., LL.D., F.R.S., Professor of Natural History in the Durham College of Science, Newcastle-on-Tyne. 2 Mowbray-villas, Sunderland.

1880. *Brady, Rev. Nicholas, M.A. Rainham Hall, Rainham, S.O., Essex.

1905. §Brakhan, A. Clare Bank, The Common, Sevenoaks.

1906. §Branfield, Wilfrid. 4 Victoria-villas, Upperthorpe, Sheffield.

1885. *Brathy, William, J.P. Alton Lodge, Lancaster Park, Harrogate.

1905 ‡Brausewetter, Miss. Roedean School, near Brighton.

1909. §Bremner, Alexander. 38 New Broad-street, E.C.

1905. ‡Bremner, R. S. Westminster-chambers, Dale-street, Liverpool.

Year of Election.

1905. ‡Bremner, Stanley. Westminster-chambers, Dale-street, Liverpool.
1902. *Brereton, Cloudesley. Briningham House, Briningham, S.O., Norfolk.
1898. §Brereton, Cuthbert A., M.Inst.C.E. 5 Queen Anne's-gate, S.W.
1882. **Bretherton, C. E. 26 Palace-mansions, Addison Bridge, W.*
1909. *Breton, Miss A. C. 15 Camden-crescent, Bath.
1905. §Brewis, E. 27 Winchelsea-road, Tottenham, N.
1908. §Brickwood, Sir John. Branksmere, Southsea.
1907. *Bridge, Henry Hamilton. North Lodge, Battle, Sussex.
1870. *Brigg, Sir John, M.P. Kildwick Hall, Keighley, Yorkshire.
1904. *Briggs, William, M.A., LL.D., F.R.A.S. Burlington House, Cambridge.
1909. §Briggs, Mrs. Owlbrigg, Cambridge.
1905. ‡Brill, J., Litt.D. Grey College, Bloemfontein, South Africa.
1908. ‡Brindley, H. H. 4 Devana-terrace, Cambridge.
1893. ‡Briscoe, Albert E., B.Sc., A.R.C.Sc. The Hoppet, Little Baddow, Chelmsford.
1904. ‡Briscoe, J. J. Bourn Hall, Bourn, Cambridge.
1905. §Briscoe, Miss. Bourn Hall, Bourn, Cambridge.
1898. ‡Bristol, The Right Rev. G. F. Browne, D.D., Lord Bishop of. 17 The Avenue, Clifton, Bristol.
1879. *Brittain, W. H., J.P., F.R.G.S. Storth Oaks, Sheffield.
1905. *Broadwood, Brigadier-General R. G. The Deodars, Bloemfontein, South Africa.
1905. §Brock, Dr. B. G. P.O. Box 216, Germiston, Transvaal.
1907. ‡Brockington, W. A., M.A. Leicestershire County Council, 38 Bowling Green-street, Leicester.
1896. *Brocklehurst, S. Olinda, Sefton Park, Liverpool.
1901. ‡Brodie, T. G., M.D., F.R.S., Professor of Physiology in the University of Toronto. The University, Toronto, Canada.
1883. *Brodie-Hall, Miss W. L. 5 Devonshire-place, Eastbourne.
1905. ‡Brodigan, C. B. Brakpan Mines, Johannesburg.
1903. ‡Brodrick, Harold, M.A., F.G.S. (Local Sec. 1903.) 7 Aughton-road, Birkdale, Southport.
1904. ‡Bromwich, T. J. I'A., M.A., F.R.S., Professor of Mathematics in Queen's College, Galway.
1906. ‡Brook, Stanley. 18 St. George's-place, York.
1905. **Brooke, Geoffrey. Christ Church Vicarage, Mirfield, S.O., Yorkshire.*
1906. *Brooks, F. T. 102 Mawson-road, Cambridge.
1883. *Brotherton, E. A., M.P. 16 St. James's-place, S.W.
1883. *Brough, Mrs. Charles S. 12 Salisbury-road, Southsea.
1886. ‡Brough, Joseph, LL.D., Professor of Logic and Philosophy in University College, Aberystwyth.
1905. ‡Brown, A. R. Trinity College, Cambridge.
1863. *Brown, Alexander Crum, M.D., LL.D., F.R.S., F.R.S.E., V.P.C.S. (Pres. B, 1874; Local Sec. 1871.) 8 Belgrave-crescent, Edinburgh.
1883. ‡Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1905. §Brown, Professor Ernest William, M.A., D.Sc., F.R.S. Yale University, New Haven, Conn., U.S.A.
1903. ‡Brown, F. W. 6 Rawlinson-road, Southport.
1870. §Brown, Horace T., LL.D., F.R.S., F.G.S. (Pres. B, 1899; Council, 1904– .) 52 Nevern-square, S.W.
1870. *Brown, J. Campbell, D.Sc., F.C.S., Professor of Chemistry in the University of Liverpool.
1905. ‡Brown, J. Ellis. Durban, Natal.

Year of Election.

1876. §BROWN, JOHN, F.R.S. (Local Sec. 1902.) Longhurst, Dunmurry, Belfast.
1881. *Brown, John, M.D. 2 Glebe-terrace, Rondebosch, Cape Colony.
1895. *Brown, John Charles, 39 Burlington-road, Sherwood, Nottingham.
1905. ‡Brown, John S. Longhurst, Dunmurry, Belfast.
1905. ‡Brown, L. Clifford. Beyer's Kloof, Klapmuts, Cape Colony.
1882. *Brown, Mrs. Mary. 2 Glebe-terrace, Rondebosch, Cape Colony.
1898. §Brown, Nicol, F.G.S. 4 The Grove, Highgate, N.
1905. ‡Brown, R. C. Strathyre, Troyville, Transvaal.
1901. ‡Brown, Professor R. N. R., B.Sc. The University, Sheffield.
1908. §Brown, Sidney G. 52 Kensington Park-road, W.
1905. §Brown, Mrs. Sidney G. 52 Kensington Park-road, W.
1908. ‡Brown, William, B.Sc. 48 Dartmouth-square, Dublin.
1906. ‡Browne, Charles E., B.Sc. Christ's Hospital, West Horsham.
1900. *Browne, Frank Balfour, M.A., F.R.S.E., F.Z.S. Claremont, Holywood, Co. Down.
1908. ‡Browne, Rev. Henry, M.A. University College, Dublin.
1895. *Browne, H. T. Doughty. 6 Kensington House, Kensington-court, W.
1879. ‡BROWNE, Sir J. CRICHTON, M.D., LL.D., F.R.S., F.R.S.E. 61 Carlisle-place-mansions, Victoria-street, S.W.
1905. *Browne, James Stark, F.R.A.S. The Red House, Mount-avenue, Ealing, W.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1905. §BRUCE, Colonel Sir DAVID, C.B., M.B., F.R.S. (Pres. I, 1905.) War Office, 68 Victoria-street, S.W.
1905. ‡Bruce, Lady. 3P Artillery-mansions, Victoria-street, S.W.
1893. ‡Bruce, William S., LL.D., F.R.S.E. Antarctica, Joppa, Edinburgh.
1902. ‡Bruce-Kingsmill, Major J., F.C.S. 4, St. Ann's-square, Manchester.
1900. *Brumm, Charles. Lismara, Grosvenor-road, Birkdale, Southport.
1896. *Brunner, Right Hon. Sir J. T., Bart., M.P. Druid's Cross, Wavertree, Liverpool.
1868. ‡BRUNTON, Sir T. LAUDER, Bart., M.D., D.Sc., F.R.S. (Council, 1908– .) 10 Stratford-place, Cavendish-square, W.
1897. *Brush, Charles F. Cleveland, Ohio, U.S.A.
1886. *BRYAN, G. H., D.Sc., F.R.S., Professor of Mathematics in University College, Bangor.
1894. ‡Bryan, Mrs. R. P. Plas Gwyn, Bangor.
1884. *BRYCE, Rev. Professor GEORGE, D.D., LL.D. Kilmadock, Winnipeg, Canada.
1901. ‡Bryce, Thomas H. 2 Granby-terrace, Hillhead, Glasgow.
1902. *Bubb, Miss E. Maude. Ullenwood, near Cheltenham.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1902. *Buchanan, Miss Florence, D.Sc. University Museum, Oxford.
1905. §Buchanan, Right Hon. Sir John. Clareinch, Claremont, Cape Town.
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡BUCHANAN, JOHN YOUNG, M.A., F.R.S., F.R.S.E., F.R.G.S., F.C.S. Christ's College, Cambridge.
1909. §Buchanan, W. W. P.O. Box 1658, Winnipeg, Canada.
1886. *Buckle, Edmund W. 23 Bedford-row, W.C.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, W.
1904. ‡Buckwell, J. C. North Gate House, Pavilion, Brighton.
1893. §BULLEID, ARTHUR, F.S.A. Dymboro, Midsomer Norton, Bath.
1903. *Bullen, Rev. R. Ashington, F.L.S., F.G.S. Englemoor, Heathside-road, Woking, Surrey.

Year of Election.

1909. §BULYEA, The Hon. G. H. V. Edmonton, Alberta, Canada.
1905. ‡Burbury, Mrs. A. A. 17 Upper Phillimore-gardens, W.
1905. ‡Burbury, Miss A. D. 17 Upper Phillimore-gardens, W.
1886. §BURBURY, S. H., M.A., F.R.S. 1 New-square, Lincoln's Inn, W.C.
1907. ‡Burch, George J., M.A., D.Sc. F.R.S. Norham Hall, Oxford.
1881. ‡Burdett-Coutts, William Lehmann, M.P. 1 Stratton-street, Piccadilly, W.
1905. ‡Burdon, E. R., M.A. Ikenhilde, Royston, Herts.
1894. ‡BURKE, JOHN B. B. Trinity College, Cambridge.
1884. *Burland, Lieut.-Colonel Jeffrey H. 342 Sherbrooke-street West, Montreal, Canada.
1905. ‡Burmeister, H. A. P. 78 Hout-street, Cape Town.
1904. ‡Burn, R. H. 21 Stanley-crescent, Notting-hill, W.
1885. *Burnett, W. Kendall, M.A. Migvie House, North Silver-street, Aberdeen.
1909. §Burns, F. D. 203 Morley-avenue, Winnipeg, Canada.
1908. ‡Burnside, W. Snow, D.Sc., Professor of Mathematics in the University of Dublin. 35 Raglan-road, Dublin.
1905. ‡Burroughes, James S., F.R.G.S. The Homestead, Seaford, Sussex.
1909. §Burrows, Theodore Arthur. 187 Kennedy-street, Winnipeg, Canada.
1909. §Burton, E. F. 129 Howland-avenue, Toronto, Canada.
1866. *BURTON, FREDERICK M., F.L.S., F.G.S. Highfield, Gainsborough.
1892. ‡Burton-Brown, Colonel Alexander, R.A., F.R.A.S., F.G.S. 11 Union-crescent, Margate.
1904. ‡Burtt, Arthur H., D.Sc. 4 South View, Holgate, York.
1906. §Burtt, Philip. Swarthmore, St. George's-place, York.
1909. §Burwash, E. M., M.A. New Westminster, British Columbia, Canada.
1887. *Bury, Henry. Mayfield House, Farnham, Surrey.
1899. §Bush, Anthony. 43 Portland-road, Nottingham.
1895. ‡Bushe, Colonel C. K., F.G.S. 19 Cromwell-road, S.W.
1906. §Bushell, H. A. Melton House, Holgate Hill, York.
1908. *Bushell, W. F. The Hermitage, Harrow.
1884. *Butcher, William Deane, M.R.C.S.Eng. Holyrood, 5 Cleveland-road, Ealing, W.
1884. *Butterworth, W. Verona, 10 Derbe-road, St. Anne's-on-the-Sea, Lancashire.
1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
1899. ‡Byles, Arthur R. 'Bradford Observer,' Bradford, Yorkshire.

1908. ‡Cadic, Edouard, D.Litt. Mon Caprice, Pembroke Park, Dublin.
1861. *Caird, James Key, LL.D. 8 Roseangle, Dundee.
1905. ‡Calderwood, J. M. P.O. Box 2295, Johannesburg.
1901. ‡Caldwell, Hugh. Blackwood, Newport, Monmouthshire.
1907. §Caldwell, K. S. St. Bartholomew's Hospital, S.E.
1908. §Caldwell, Colonel R. T., M.A., LL.M., LL.D., Master of Corpus Christi College, Cambridge.
1897. §CALLENDAR, HUGH L., M.A., LL.D., F.R.S. (Council, 1900-06), Professor of Physics in the Imperial College of Science, S.W.
1857. ‡CAMERON, Sir CHARLES A., C.B., M.D. 51 Pembroke-road, Dublin.
1909. §Cameron, D. C. 65 Roslyn-road, Winnipeg, Canada.
1896. §Cameron, Irving H. 307 Sherbourne-street, Toronto, Canada.
1909. §Cameron, Hon. Mr. Justice J. D. Judges' Chambers, Winnipeg, Canada.

Year of Election.

1901. §Campbell, Archibald. Park Lodge, Albert-drive, Pollokshields, Glasgow.
1897. ‡Campbell, Colonel J. C. L. Achalader, Blairgowrie, N.B.
1909. *Campbell, R. J. Rideau Hall, 85 Kennedy-street, Winnipeg, Canada.
1909. §Campbell, Mrs. R. J. Rideau Hall, 85 Kennedy-street, Winnipeg, Canada.
1902. ‡Campbell, Robert. 21 Great Victoria-street, Belfast.
1890. ‡CANNAN, Professor EDWIN, M.A., LL.D., F.S.S. (Pres. F, 1902.) 46 Wellington-square, Oxford.
1905. ‡Cannan, Gilbert. King's College, Cambridge.
1897. §Cannon, Herbert. Woodbank, Erith, Kent.
1905. ‡Cape Town, The Archbishop of. Bishop's-court, Claremont, Cape Colony.
1904. ‡Capell, Rev. G. M. Passenham Rectory, Stony Stratford.
1905. *Caporn, Dr. A. W. Roeland-street Baths, Cape Town.
1894. ‡CAPPER, D. S., M.A., Professor of Mechanical Engineering in King's College, W.C.
1896. *Carden, H. Vandeleur. Fassaroe, Walmer.
1909. §Carmichael, D. C. Limpley Stoke, Bath.
1902. ‡Carpenter, G. H., B.Sc., Professor of Zoology in the Royal College of Science, Dublin.
1906. *Carpenter, H. C. H. 11 Oak-road, Withington, Manchester.
1905. §Carpmael, Edward, F.R.A.S., M.Inst.C.E. 24 Southampton-buildings, Chancery-lane, W.C.
1893. ‡CARR, J. WESLEY, M.A., F.L.S., F.G.S., Professor of Biology in University College, Nottingham.
1906. *Carr, Richard E., British Vice-Consul, Cordoba, Spain.
1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1905. ‡Carrick, Dr. P.O. Box 646, Johannesburg.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. (Pres. D, 1886.) 14 Vermont-road, Norwood, S.E.
1886. ‡CARSLAKE, J. BARHAM. (Local Sec. 1886.) 30 Westfield-road, Birmingham.
1899. ‡Carslaw, H. S., D.Sc., Professor of Mathematics in the University of Sydney, N.S.W.
1868. *Carteighe, Michael, F.C.S., F.I.C. Oriel, Goring, Reading.
1900. *Carter, W. Lower, M.A., F.G.S. East London College, Mile End-road, E.
1896. ‡Cartwright, Miss Edith G. 21 York Street-chambers, Bryanston-square, W.
1878. *Cartwright, Ernest H., M.A., M.D. Myskyns, Ticehurst, Sussex.
1870. §Cartwright, Joshua, M.Inst.C.E., F.S.I. 21 Parsons-lane, Bury, Lancashire.
1862. ‡Carulla, F. J. R. 84 Rosehill-street, Derby.
1894. ‡Carus, Dr. Paul. La Salle, Illinois, U.S.A.
1901. ‡Carver, Thomas A. B., D.Sc., Assoc.M.Inst.C.E. 118 Napiershall-street, Glasgow.
1899. **Case, J. Monckton. Town Office, Uitenhage, Cape Colony.*
1897. *Case, Willard E. Auburn, New York, U.S.A.
1873. *Cash, William, F.G.S. 26 Mayfield-terrace South, Halifax.
1904. ‡*Caspair, W. A. National Physical Laboratory, Bushy House, Teddington, Middlesex.*
1908. *Cave, Charles J. P., M.A. Ditcham Park, Petersfield.
1886. *Cave-Moyle, Mrs. Isabella. St. Paul's Vicarage, Cheltenham.
Cayley, Digby. Brompton, near Scarborough.
1905. *Challenor, Bromley, M.A. The Firs, Abingdon.

Year of
Election.

1905. *Challenor, Miss E. M. The Firs, Abingdon.
1905. ‡Chamberlain, Miss H. H. Ingleneuk, Upper St. John's-road, Sea Point, Cape Colony.
1901. §Chamen, W. A. South Wales Electrical Power Distribution Company, Royal-chambers, Queen-street, Cardiff.
1905. ‡Champion, G. A. Haraldene, Chelmsford-road, Durban, Natal.
1881. *Champney, John E. 27 Hans-place, S.W.
1908. ‡Chance, Sir Arthur, M.D. 90 Merrion-square, Dublin.
1907. *Chapman, Alfred Chaston, F.I.C. 8 Duke-street, Aldgate, E.C.
1902. §Chapman, D. L. 10 Parsonage-road, Withington, Manchester.
1899. §Chapman, Professor Sydney John, M.A., M.Com. (Pres. F, 1909.) Burnage Lodge, Levenshulme, Manchester.
1905. ‡Chassigneux, E. 12 Tavistock-road, Westbourne-park, W.
1903. ‡Chaster, G. W. 42 Talbot-street, Southport.
1904. *Chattaway, F. D., M.A., D.Sc., Ph.D., F.R.S. 47 Beechcroft-road, Oxford.
1884. *Chatterton, George, M.A., M.Inst.C.E. 6 The Sanctuary, Westminster, S.W.
1886. *Chattock, A. P., M.A., Professor of Experimental Physics in University College, Bristol.
1904. *Chaundy, Theodore William. 49 Broad-street, Oxford.
1900. §Cheesman, W. Norwood, J.P., F.L.S. The Crescent, Selby.
1874. *Chermside, Lieut.-General Sir H. C., R.E., G.C.M.G., C.B. Newstead Abbey, Nottingham.
1908. ‡Cherry, Right Hon. R. R. 92 St. Stephen's Green, Dublin.
1879. *Chesterman, W. Belmayne, Sheffield.
1908. ‡Chill, Edwin, M.D. Westleigh, Mattock-road, Ealing, W.
1883. ‡Chinery, Edward F. Monmouth House, Lymington.
1884. ‡Chipman, W. W. L. 957 Dorchester-street, Montreal, Canada.
1894. ‡Chisholm, G. G., M.A., B.Sc., F.R.G.S. (Pres. E, 1907.) 12 Hallhead-road, Edinburgh.
1899. §Chitty, Edward. Sonnenberg, Castle-avenue, Dover.
1899. ‡Chitty, Mrs. Edward. Sonnenberg, Castle-avenue, Dover.
1899. §Chitty, G. W. Brockhill Park, Hythe, Kent.
1904. ‡Chivers, John, J.P. Histon, Cambridgeshire.
1882. ‡Chorley, George. Midhurst, Sussex.
1909. §Chow, H. H., M.D. 263 Broadway, Winnipeg, Canada.
1893. *Chree, Charles, D.Sc., F.R.S. Kew Observatory, Richmond, Surrey.
1900. *Christie, R. J. Duke-street, Toronto, Canada.
1875. *Christopher, George, F.C.S. May Villa, Lucien-road, Tooting Common, S.W.
1876. *Chrystal, George, M.A., LL.D., F.R.S.E. (Pres. A, 1885), Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1905. ‡Chudleigh, C. P.O. Box 743, Johannesburg.
1870. §Church, Sir A. H., K.C.V.O., M.A., F.R.S., F.S.A., Professor of Chemistry in the Royal Academy of Arts. Shelsley, Ennerdale-road, Kew.
1898. §Church, Colonel G. Earl, F.R.G.S. (Pres. E, 1898.) 216 Cromwell-road, S.W.
1903. ‡Clapham, J. H., M.A. King's College, Cambridge.
1901. §Clark, Professor Archibald B., M.A. University of Manitoba Winnipeg, Canada.
1905. *Clark, Cumberland, F.R.G.S. 29 Chepstow-villas, Bayswater, W.
1907. *Clark, Mrs. Cumberland. 29 Chepstow-villas, Bayswater, W.
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.

Year of Election.

1902. ‡Clark, G. M. South African Museum, Cape Town.
1908. ‡Clark, James, B.Sc. Newtown School, Waterford, Ireland.
1881. *Clark, J. Edmund, B.A., B.Sc. Asgarth, Riddlesdown-road, Purley, Surrey.
1909. §Clark, J. M., K.C. 16 King-street West, Toronto, Canada.
1908. §Clark, John R. W. Brothock Bank House, Arbroath, Scotland.
1901. *Clark, Robert M., B.Sc., F.L.S. 27 Albyn-place, Aberdeen.
1907. *Clarke, E. Russell. 11 King's Bench-walk, Temple, E.C.
1902. *CLARKE, Miss LILIAN J., B.Sc., F.L.S. James Allen's Girls' School, East Dulwich, S.E.
1905. ‡Clarke, Rev. W. E. C., M.A. P.O. Box 1144, Pretoria.
1889. *CLAYDEN, A. W., M.A., F.G.S. 5 The Crescent, Mount Radford, Exeter.
1908. *Clayton, Miss Edith M. Brackendene, Horsell, Surrey.
1909. §Cleeves, Frederick, F.Z.S. 23 Lime-street, E.C.
1909. §Cleeves, W. B. Public Works Department, Government-buildings, Pretoria.
1861. ‡CLELAND, JOHN, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 The University, Glasgow.
1905. §Cleland, Mrs. 2 The University, Glasgow.
1905. §Cleland, J. R. 2 The University, Glasgow.
1902. ‡Clements, Olaf P. Tana, St. Bernard's-road, Olton, Warwick.
1904. §CLERK, DUGALD, F.R.S., M.Inst.C.E. (Pres. G, 1908.) 18 Southampton-buildings, W.C.
1909. §Cleve, Miss E. K. P. 74 Kensington Gardens-square, W.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. 3 Bardwell-road, Banbury-road, Oxford.
1906. §CLOSE, Colonel C. F., R.E., C.M.G., F.R.G.S. (Council, 1908– .) Army and Navy Club, Pall Mall, S.W.
1883. *CLOWES, FRANK, D.Sc., F.C.S. (Local Sec. 1893.) The Grange, College-road, Dulwich, S.E.
1891. *Coates, Henry, F.R.S.E. Balure, Perth.
1903. *Coates, W. M. Queens' College, Cambridge.
1884. §Cobb, John. Fitzharris, Abingdon.
1908. *Cochrane, Miss Constance. The Downs, St. Neots.
1864. *Cochrane, James Henry. Burston House, Pittville, Cheltenham.
1908. ‡Cochrane, Robert, I.S.O., LL.D., F.S.A. 17 Highfield-road, Dublin.
1901. ‡Cockburn, Sir John, K.C.M.G., M.D. 10 Gatestone-road, Upper Norwood, S.E.
1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1861. *Coe, Rev. Charles C., F.R.G.S. Whinsbridge, Grosvenor-road, Bournemouth.
1908. ‡Coffey, Denis J., M.B. 2 Arkendale-road, Glenageary, Co. Dublin.
1898. ‡Coffey, George. 5 Harcourt-terrace, Dublin.
1881. *COFFIN, WALTER HARRIS, F.C.S. Passaic, Kew.
1896. *Coghill, Percy de G. 4 Sunnyside, Prince's Park, Liverpool.
1901. §Cohen, N. L. 11 Hyde Park-terrace, W.
1901. *Cohen, R. Waley, B.A. 11 Sussex-square, W.
1909. *Coke, Elmsley, M.Inst.C.E., F.G.S. 26 Low Pavement, Nottingham.
1906. *Coker, Professor Ernest George, M.A., D.Sc., F.R.S.E. City and Guilds of London Technical College, Finsbury, E.C.
1895. *Colby, James George Ernest, M.A., F.R.C.S. Malton, Yorkshire.
1895. *Colby, William Henry. Carregwen, Aberystwyth.
1893. §Cole, Grenville A. J., F.G.S., Professor of Geology in the Royal College of Science, Dublin.

Year of Election.

1903. ‡Cole, Otto B. 551 Boylston-street, Boston, U.S.A.
1897. §COLEMAN, Professor A. P., M.A., Ph.D. 476 Huron-street, Toronto, Canada.
1899. §Coleman, William, F.R.A.S. The Shrubbery, Buckland, Dover.
1899. ‡Collard, George. The Gables, Canterbury.
1892. ‡Collet, Miss Clara E. 7 Coleridge-road, N.
1887. ‡COLLIE, J. NORMAN, Ph.D., F.R.S., Professor of Organic Chemistry in the University of London. 16 Campden-grove, W.
1893. ‡Collinge, Walter E. The University, Birmingham.
1861. *Collingwood, J. Frederick, F.G.S. 5 Irene-road, Parson's Green, S.W.
1876. ‡COLLINS, J. H., F.G.S. Crinnis House, Par Station, Cornwall.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1905. ‡Collins, Rev. Spencer. The Rectory, Victoria West, Cape Colony.
1902. ‡Collins, T. R. Belfast Royal Academy, Belfast.
1907. ‡COLSON, ALFRED, M.Inst.C.E. (Local Sec. 1907.) Millstone-lane, Leicester.
1905. *Combs, Rev. Cyril W., M.A. Elverton, Castle-road, Newport, Isle of Wight.
1871. *Connor, Charles C. 10 College-gardens, Belfast.
1902. ‡Conway, A. W. 100 Leinster-road, Rathmines, Dublin.
1903. ‡Conway, R. Seymour, Litt.D., Professor of Latin in Owens College, Manchester.
1898. §Cook, Ernest H. 27 Berkeley-square, Clifton, Bristol.
1876. *COOKE, CONRAD W. The Pines, Langland-gardens, Hampstead, N.W.
1888. ‡Cooley, George Parkin. Constitutional Club, Nottingham.
1899. *Coomaraswamy, A. K., D.Sc., F.L.S., F.G.S. Broad Campden, Gloucestershire.
1902. *Coomaraswamy, Mrs. A. K. Broad Campden, Gloucestershire.
1903. §Cooper, Miss A. J. 22 St. John-street, Oxford.
1901. *Cooper, C. Forster, B.A. Trinity College, Cambridge.
1907. ‡Cooper, William. Education Offices, Becket-street, Derby.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1904. *COPEMAN, S. MONCKTON, M.D., F.R.S. Local Government Board, Whitehall, S.W.
1909. §Copland, Mrs. A. J. Gleniffer, 50 Woodberry Down, N.
1904. *Copland, Miss Louisa. 10 Wynnstay-gardens, Kensington, W.
1905. ‡Corben, J. H. Education Department, Klerksdorp, Transvaal.
1901. ‡Corbett, A. Cameron, M.P. Thornliebank House, Glasgow.
1909. §Corbett, W. A. 615 Main-street, Winnipeg, Canada.
1887. *Corcoran, Bryan. Fairlight, 22 Oliver-grove, South Norwood, S.E.
1894. §Corcoran, Miss Jessie R. The Chestnuts, Mulgrave-road, Sutton, Surrey.
1883. *Core, Professor Thomas H., M.A. Groombridge House, Withington, Manchester.
1901. *Cormack, Professor J. D., B.Sc. University College, Gower-street, W.C.
1893. *Corner, Samuel, B.A., B.Sc. Abbotsford House, Waverley-street, Nottingham.
1889. ‡CORNISH, VAUGHAN, D.Sc., F.R.G.S. 31 Kensington Gardens-square, W.
1905. ‡Cornish-Bowden, A. H. Surveyor-General's Office, Cape Town.
1884. *Cornwallis, F. S. W., F.L.S. Linton Park, Maidstone.
1888. ‡Corser, Rev. Richard K. 57 Park Hill-road, Croydon.
1900. §Cortie, Rev. A. L., S.J., F.R.A.S. Stonyhurst College, Blackburn.
1905. ‡Cory, Professor G. E., M.A. Rhodes University College, Grahamstown, Cape Colony.
1909. *Cossar, G. C., M.A., F.G.S. Southview, Murrayfield, Edinburgh.

Year of Election.

1908. *Costello, John Francis, B.A. The Rectory, Ballymackey, Nenagh, Ireland.
1906. ‡Cotsworth, Moses B. Acomb, York.
1906. §Cotter, J. R. 21 Mayfield-road, Terenure Park, Dublin.
1874. *COTTERILL, J. H., M.A., F.R.S. Braeside, Speldhurst, Kent.
1908. ‡Cotton, Alderman W. F., D.L., J.P. Hollywood, Co. Dublin.
1905. ‡Cottrill, G. St. John, P.O. Box 4829, Johannesburg.
1904. ‡Coulter, G. G. 28 Pall Mall, S.W.
1908. ‡Courtenay, Colonel Arthur H., C.B., D.L. United Service Club, Dublin.
1896. ‡COURTNEY, Right Hon. Lord. (Pres. F, 1896.) 15 Cheyne-walk, Chelsea, S.W.
1905. ‡Cousens, R. L. P.O. Box 4261, Johannesburg.
1908. ‡Cowan, P. C., B.Sc., M.Inst.C.E. 33 Ailesbury-road, Dublin.
1872. *Cowan, Thomas William, F.L.S., F.G.S. Upcott House, Taunton, Somersetshire.
1903. ‡Coward, H. Knowle Board School, Bristol.
1900. §Cowburn, Henry. Dingle Head, Leigh, Lancashire.
1905. ‡Cowell, John Ray. P.O. Box 2141, Johannesburg.
1895. *COWELL, PHILIP H., M.A., F.R.S. Royal Observatory, Greenwich, and 74 Vanbrugh-park, Blackheath, S.E.
1899. ‡Cowper-Coles, Sherard, Assoc.M.Inst.C.E. 82 Victoria-street, S.W.
1867. *Cox, Edward. Cardean, Meigle, N.B.
1909. §Cox, F. J. C. Anderson-avenue, Winnipeg, Canada.
1906. §Cox, S. Herbert, Professor of Mining in the Royal College of Science, S.W.
1905. ‡Cox, W. H. Royal Observatory, Cape Town.
1902. ‡*Craig, H. C. Strandtown, Belfast.*
1908. ‡Craig, James, M.D. 18 Merrion-square North, Dublin.
1884. §CRAIGIE, Major P. G., C.B., F.S.S. (Pres. F, 1900; Council, 1908– .) West Wellow, Romsey, Hampshire.
1906. ‡Craik, Sir Henry, K.C.B., LL.D., M.P. 5A Dean's-yard, Westminster, S.W.
1908. *Cramer, W., Ph.D., D.Sc. Physiological Department, The University, Edinburgh.
1906. §Cramp, William. Redthorn, Whalley-road, Manchester.
1905. *Cranswick, Wm. Franceys. 34 Boshof-road, Kimberley.
1906. ‡CRAVEN, HENRY. (Local Sec. 1906.) Clifton Green, York.
1887. **Craven, Thomas, J.P. Woodheyes-Park, Ashton-upon-Mersey.*
1905. ‡Crawford, Mrs. A. M. Marchmont, Rosebank, near Cape Town.
1905. ‡Crawford, Professor Lawrence, M.A., D.Sc., F.R.S.E. South African College, Cape Town.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Colinton-road, Edinburgh.
1905. ‡Crawford, W. C., jun. 1 Lockharton-gardens, Colinton-road, Edinburgh.
1871. *CRAWFORD AND BALCARRES, The Right Hon. the Earl of, K.T., LL.D., F.R.S., F.R.A.S. 2 Cavendish-square, W.; and Haigh Hall, Wigan.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, N.
1885. §CREAK, Captain E. W., C.B., R.N., F.R.S. (Pres. E, 1903; Council, 1896–1903.) 9 Hervey-road, Blackheath, S.E.
1876. *Crewdson, Rev. Canon George. St. Mary's Vicarage, Windermere.
1887. *Crewdson, Theodore. Spurs, Styall, Handforth, Manchester.
1904. ‡Crilly, David. 7 Well-street, Paisley.

Year of Election.

1880. *Crisp, Sir Frank, B.A., LL.B., F.L.S., F.G.S. 5 Lansdowne-road, Notting Hill, W.
1908. §Crocker, J. Meadmore. Albion House, Bingley, Yorkshire.
1905. §Croft, Miss Mary. 17 Pelham-crescent, S.W.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1908. §Crofts, D. G. Cadastral Survey, Nairobi, East African Protectorate.
1878. *Croke, John O'Byrne, M.A. Clouneagh, Ballingarry-Lacy, Co. Limerick.
1903. *Crompton, Holland. Oaklyn, Cross Oak-road, Berkhamsted.
1901. ‡CROMPTON, Colonel R. E., C.B., M.Inst.C.E. (Pres. G, 1901.) Kensington-court, W.
1887. ‡CROOK, HENRY T., M.Inst.C.E. 9 Albert-square, Manchester.
1898. §CROOKE, WILLIAM. Langton House, Charlton Kings, Cheltenham.
1865. §CROOKES, Sir WILLIAM, D.Sc., F.R.S., V.P.C.S. (PRESIDENT, 1898; Pres. B, 1886; Council, 1885–91.) 7 Kensington Park-gardens, W.
1879. ‡Crookes, Lady. 7 Kensington Park-gardens, W.
1897. *CROOKSHANK, E. M., M.B. Ashdown Forest, Forest Row, Sussex.
1909. §Crosby, Rev. E. H. Lewis, B.D. 36 Rutland-square, Dublin.
1905. ‡Crosfield, Hugh T. Walden, Coombe-road, Croydon.
1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
1870. *CROSFIELD, WILLIAM. 3 Fulwood-park, Liverpool.
1904. §Cross, Professor Charles R. Massachusetts Institute of Technology, Boston, U.S.A.
1890. ‡Cross, E. Richard, LL.B. Harwood House, New Parks-crescent, Scarborough.
1905. §Cross, Robert. 13 Moray-place, Edinburgh.
1904. *CROSSLEY, A. W., D.Sc., Ph.D., F.R.S., Professor of Chemistry to the Pharmaceutical Society of Great Britain. 10 Crediton-road, West Hampstead, N.W.
1908. ‡Crossley, F. W. 30 Molesworth-street, Dublin.
1887. *Crossley, Sir William J., Bart., M.P. Glenfield, Bowdon, Cheshire.
1894. *Crosweller, William Thomas, F.Z.S., F.I.Inst. Kent Lodge, Sidcup, Kent.
1897. *Crosweller, Mrs. W. T. Kent Lodge, Sidcup, Kent.
1890. *Crowley, Ralph Henry, M.D. 116 Manningham-lane, Bradford.
1883. *CULVERWELL, EDWARD P., M.A., Professor of Education in Trinity College, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1898. ‡Cundall, J. Tudor. 1 Dean Park-crescent, Edinburgh.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1905. ‡Cunningham, Miss A. 2 St. Paul's-road, Cambridge.
1882. *CUNNINGHAM, Lieut.-Colonel ALLAN, R.E., A.I.C.E. 20 Essex-villas, Kensington, W.
1905. ‡Cunningham, Andrew. Earlsferry, Campground-road, Mowbray, South Africa.
1885. ‡CUNNINGHAM, J. T., B.A. Biological Laboratory, Plymouth.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.
1883. *CUNNINGHAM, Rev. W., D.D., D.Sc. (Pres. F, 1891, 1905.) Trinity College, Cambridge.
1892. ‡Cunningham-Craig, E. H., B.A., F.G.S. 14A Dublin-street, Edinburgh.
1900. *Cunnington, William A., M.A., Ph.D., F.Z.S. 25 Orlando-road, Clapham Common, S.W.

Year of Election.

1908. ‡Currelly, C. T., M.A., F.R.G.S. United Empire Club, 117 Piccadilly, W.

1892. *Currie, James, M.A., F.R.S.E. Larkfield, Wardie-road, Edinburgh.

1905. ‡Currie, Dr. O. J. Manor House, Mowbray, Cape Town.

1905. ‡Currie, W. P. P.O. Box 2010, Johannesburg.

1902. ‡Curry, Professor M., M.Inst.C.E. 5 King's-gardens, Hove.

1883. ‡Cushing, Mrs. M. Rosslynlee, Woodside Green, South Norwood, S.E.

1881. §Cushing, Thomas, F.R.A.S. Rosslynlee, Woodside Green, South Norwood, S.E.

1907. ‡Cushny, Arthur R., M.D., F.R.S., Professor of Pharmacology in University College, Gower-street, W.C.

1898. §Dalby, W. E., D.Sc., M.Inst.C.E., Professor of Civil and Mechanical Engineering in the City and Guilds of London Institute, Exhibition-road, S.W.

1889. *Dale, Miss Elizabeth. Garth Cottage, Oxford-road, Cambridge.

1906. §Dale, William, F.S.A., F.G.S. The Lawn, Archer's-road, Southampton.

1907 ‡DALGLIESH, RICHARD, J.P., D.L. Ashfordby Place, near Melton Mowbray.

1904. *DALTON, J. H. C., M.D. The Plot, Adams-road, Cambridge.

1862. ‡DANBY, T. W., M.A., F.G.S. The Crouch, Seaford, Sussex.

1905. §Daniel, Miss A. M. 3 St. John's-terrace, Weston-super-Mare.

1901. ‡Daniell, G. F., B.Sc. Woodberry, Oakleigh Park, N.

1896. §Danson, F. C. Tower-buildings, Water-street, Liverpool.

1849. *Danson, Joseph. Montreal, Canada.

1897. §Darbishire, F. V., B.A., Ph.D. South-Eastern Agricultural College, Wye, Kent.

1903. ‡Darbishire, Dr. Otto V. The University, Manchester.

1904. *Darwin, Charles Galton. Newnham Grange, Cambridge.

1899. *Darwin, Erasmus. The Orchard, Huntingdon-road, Cambridge.

1882. *DARWIN, FRANCIS, M.A., M.B., LL.D., D.Sc., F.R.S., F.L.S. (PRESIDENT, 1908; Pres. D, 1891; Pres. K, 1904; Council, 1882–84, 1897–1901.) 13 Madingley-road, Cambridge.

1881. *DARWIN, Sir GEORGE HOWARD, K.C.B., M.A., LL.D., F.R.S., F.R.A.S. (PRESIDENT, 1905; Pres. A, 1886; Council, 1886–1892.) Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Newnham Grange, Cambridge.

1905. ‡Darwin, Lady. Newnham Grange, Cambridge.

1878. *DARWIN, HORACE, M.A., F.R.S. The Orchard, Huntingdon-road, Cambridge.

1894. *DARWIN, Major LEONARD, Pres. R.G.S. (Pres. E, 1896; Council, 1899–1905.) 12 Egerton-place, South Kensington, S.W.

1882. ‡Darwin, W. E., B.A., F.G.S. 11 Egerton-place, S.W.

1908. ‡Davey, H. 15 Victoria-road, Brighton.

1880. *DAVEY, HENRY, M.Inst.C.E. Conaways, Ewell, Surrey.

1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, E.C.

1904. §Davidge, H. T., B.Sc., Professor of Electricity in the Ordnance College, Woolwich.

1909. §Davidson, A. R. 150 Stradbrooke-place, Winnipeg, Canada.

1902. *Davidson, S. C. Seacourt, Bangor, Co. Down.

1887. *Davies, H. Rees. Treborth, Bangor, North Wales.

1904. §Davies, Henry N., F.G.S. St. Chad's, Weston-super-Mare.

1906. ‡Davies, S. H. Ryecroft, New Earswick, York.

Year of Election.

1893. *Davies, Rev. T. Witton, B.A., Ph.D., D.D., Professor of Semitic Languages in University College, Bangor, North Wales.
1896. *Davies, Thomas Wilberforce, F.G.S. 41 Park-place, Cardiff.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.
1873. *Davis, Alfred. 37 Ladbroke-grove, W.
1905. ‡Davis, C. R. S. National Bank-buildings, Johannesburg.
1896. *Davis, John Henry Grant. The Hawthorns, Sutton-road, Walsall.
1905. §Davis, Luther. P.O. Box 898, Johannesburg.
1885. *Davis, Rev. Rudolf. 4 Alexandra-terrace, Gloucester.
1905. ‡Davy, Mrs. Alice Burtt. P.O. Box 434, Pretoria.
1905. ‡Davy, Joseph Burtt, F.R.G.S., F.L.S. P.O. Box 434, Pretoria.
1864. ‡DAWKINS, W. BOYD, D.Sc., F.R.S., F.S.A., F.G.S. (Pres. C, 1888; Council, 1882–88.) Fallowfield House, Fallowfield, Manchester.
1885. *Dawson, Lieut.-Colonel H. P., R.A. Hartlington Hall, Burnsall, Skipton-in-Craven.
1901. *Dawson, P. The Acre, Maryhill, Glasgow.
1905. ‡Dawson, Mrs. The Acre, Maryhill, Glasgow.
1884. ‡DAWSON, SAMUEL. (Local Sec. 1884.) 258 University-street, Montreal, Canada.
1906. §Dawson, William Clarke. 16 Parliament-street, Hull.
1859. *Dawson, Captain W. G. 31 King's-gardens, West End-lane, N.W.
1909. §Day, Miss M. Edith. 290 Portage-avenue, Winnipeg, Canada.
1900. ‡Deacon, M. Whittington House, near Chesterfield.
1909. §Dean, George, F.R.G.S. 5 Wordsworth-mansions, Queen's Club-gardens, W.
1901. *Deasy, Captain H. H. P. 24 Evelyn-gardens, S.W.
1884. *Debenham, Frank, F.S.S. 1 Fitzjohn's-avenue, N.W.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S. (Pres. B, 1869; Council, 1870–75.) 4 Schlangenweg, Cassel, Hessen.
1893. *Deeley, R. M. Melbourne House, Osmaston-road, Derby.
1878. ‡DELANY, Very Rev. WILLIAM, LL.D. University College, Dublin.
1908. *Delf, Miss E. M. Westfield College, Hampstead, N.W.
1907. ‡De Lisle, Mrs. Edwin. Charnwood Lodge, Coalville, Leicestershire.
1896. ‡Dempster, John. Tynron, Noctorum, Birkenhead.
1902. ‡Dendy, Arthur, D.Sc., F.R.S., F.L.S., Professor of Zoology in King's College, London, W.C.
1908. ‡Dennehy, W. F. 23 Leeson-park, Dublin.
1889. §DENNY, ALFRED, F.L.S., Professor of Biology in the University of Sheffield.
1905. ‡Denny, G. A. 603–4 Consolidated-buildings, Fox-street, Johannesburg.
1909. §Dent, Edward, M.A. 2 Carlos-place, W.
1874. *Derham, Walter, M.A., LL.M., F.G.S. Junior Carlton Club, Pall Mall, S.W.
1907. *Desch, Cecil H., D.Sc., Ph.D. 93 Mount Pleasant-road, South Tottenham, N.
1908. §Despard, Miss Kathleen M. 6 Sutton Court-mansions, Grove Park-terrace, Chiswick.
1894. *Deverell, F. H. 7 Grote's-place, Blackheath, S.E.
1903. ‡*Devereux, Rev. E. R. Price. Drachenfeld, Tenison-avenue, Cambridge.*
1868. *DEWAR, Sir JAMES, M.A., LL.D., D.Sc., F.R.S., F.R.S.E., V.P.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. (PRESIDENT, 1902; Pres. B, 1879; Council, 1883–88.) 1 Scroope-terrace, Cambridge.

Year of Election.

1881. ‡Dewar, Lady. 1 Scroope-terrace, Cambridge.
1884. *Dewar, William, M.A. Horton House, Rugby.
1905. ‡Dewhirst, Miss May. Pembroke House, Oxford-road, Colchester.
1901. ‡Dick, George Handasyde. 31 Hamilton-drive, Hillhead, Glasgow.
1908. §Dicks, Henry. Haslecourt, Horsell, Woking.
1904. ‡Dickson, Charles Scott, K.C., LL.D. Carlton Club, Pall Mall, S.W.
1881. ‡Dickson, Edmund, M.A., F.G.S. Claughton House, Garstang, R.S.O., Lancashire.
1887. §Dickson, H. N., D.Sc., F.R.S.E., F.R.G.S. The Lawn, Upper Redlands-road, Reading.
1902. ‡Dickson, James D. Hamilton, M.A., F.R.S.E. 6 Cranmer-road, Cambridge.
1862. *Dilke, The Right Hon. Sir Charles Wentworth, Bart., M.P., F.R.G.S. 76 Sloane-street, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1908. ‡Dines, J. S. 4 Larkfield-road, Richmond, Surrey.
1901. §Dines, W. H., F.R.S. Pyrton Hill, Watlington.
1900. §Divers, Dr. Edward, F.R.S. (Pres. B, 1902.) 3 Canning-place, Palace Gate, W.
1898. *Dix, John William S. Hampton Lodge, Durdham Down, Clifton, Bristol.
1905. §Dixey, F. A., M.A., M.D. Wadham College, Oxford.
1899. *Dixon, A. C., D.Sc., F.R.S., Professor of Mathematics in Queen's College, Belfast. Hurstwood, Malone Park, Belfast.
1874. *Dixon, A. E., M.D., Professor of Chemistry in Queen's College, Cork.
1900. ‡Dixon, A. Francis, Sc.D., Professor of Anatomy in the University of Dublin.
1905. ‡Dixon, Miss E. K. Fern Bank, St. Bees, S.O.
1908. ‡Dixon, Edward K., M.E., M.Inst.C.E. Castlebar, Co. Mayo.
1888. ‡Dixon, Edward T. Racketts, Hythe, Hampshire.
1908. *Dixon, Ernest, F.G.S. The Museum, Jermyn-street, S.W.
1900. *Dixon, Major George, M.A. St. Bees, Cumberland.
1879. *Dixon, Harold B., M.A., F.R.S., F.C.S. (Pres. B, 1894), Professor of Chemistry in the Victoria University, Manchester.
1902. ‡Dixon, Henry H., D.Sc., F.R.S., Professor of Botany in the University of Dublin. Clevedon, Temple-road, Dublin.
1908. *Dixon, Walter, F.R.M.S. Derwent, 30 Kelvinside-gardens, Glasgow.
1907. *Dixon, Professor Walter E. The Museums, Cambridge.
1902. ‡Dixon, W. V. Scotch Quarter, Carrickfergus.
1896. §Dixon-Nuttall, F. R. Ingleholme, Eccleston Park, Prescot.
1890. ‡Dobbie, James J., D.Sc., LL.D., F.R.S., Principal of the Government Laboratories. 13 Clement's Inn-passage, W.C.
1885. §Dobbin, Leonard, Ph.D. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. Castle Dobbs, Carrickfergus, Co. Antrim.
1902. ‡Dobbs, F. W. 2 Willowbrook, Eton, Windsor.
1905. ‡Dobson, Professor J. H. Transvaal Technical Institute, Johannesburg.
1908. ‡Dodd, Hon. Mr. Justice. 26 Fitzwilliam-square, Dublin.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1905. ‡Dodds, Dr. W. J. Valkenberg, Mowbray, Cape Colony.
1889. ‡Dodson, George, B.A. Downing College, Cambridge.
1904. ‡Doncaster, Leonard, M.A. The University, Birmingham.
1896. ‡Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.

Year of Election.

1901. ‡Donnan, F. G., M.A., Ph.D., Professor of Physical Chemistry. The University, Liverpool.
1905. ‡Donnan, H. Allandale, Claremont, Cape Colony.
1905. ‡Donner, Arthur. Helsingfors, Finland.
1905. §Donovan, Surgeon-General William, C.B. Army Headquarters, Pretoria.
1905. §Dornan, Rev. S. S. P.O. Box 510, Bulawayo, South Rhodesia, South Africa.
1863. *Doughty, Charles Montagu. 26 Grange-road, Eastbourne.
1909. §Douglas, A. J., M.D. City Health Department, Winnipeg, Canada.
1909. *Douglas, James. 99 John-street, New York, U.S.A.
1905. ‡Douglas-McMillan, Mrs. A. 31 Ford-street, Jeppestown, Transvaal.
1884. ‡Dove, Miss Frances. Wycombe Abbey School, Buckinghamshire.
1903. ‡Dow, Miss Agnes R. 81 Park-mansions, Knightsbridge, S.W.
1884. *Dowling, D. J. Sycamore, Clive-avenue, Hastings.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, J. Emerson, M.Inst.C.E. 11 Embankment-gardens, Chelsea, S.W.
1883. ‡Draper, William. De Grey House, St. Leonard's, York.
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1905. ‡Drew, H. W., M.B., M.R.C.S. Mocollup Castle, Ballyduff, S.O., Co. Waterford.
1906. *Drew, Joseph Webster, M.A., LL.M. Fashoda, Scarborough.
1906. *Drew, Mrs. Fashoda, Scarborough.
1908. §Droop, J. P. 11 Cleveland-gardens, Hyde Park, W.
1893. §Druce, G. Claridge, M.A., F.L.S. (Local Sec. 1894.) Yardley Lodge, 9 Crick-road, Oxford.
1909. *Drugman, Julien, Ph.D., M.Sc. Maison Négrin, La Bocca, Cannes, France.
1905. ‡Drury, H. P.O. Box 2305, Johannesburg.
1905. ‡Drury, Mrs. H. P.O. Box 2305, Johannesburg.
1907. §Drysdale, Charles V. Northampton Institute, Clerkenwell, E.C.
1892. ‡Du Bois, Professor Dr. H. Herwarthstrasse 4, Berlin, N.W.
1856. *Ducie, The Right Hon. Henry John Reynolds Moreton, Earl of, F.R.S., F.G.S. 16 Portman-square, W.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. 7 Grey Friars, Chester.
1900. *Duckworth, W. L. H., M.D., Sc.D. Jesus College, Cambridge.
1895. *Duddell, William, F.R.S. 47 Hans-place, S.W.
1906. ‡Dudgeon, Gerald C., Superintendent of Agriculture for British West Africa. Bathurst, Gambia, British West Africa.
1904. *Duffield, W. Geoffrey. Physical Laboratory, The University, Manchester.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1909. §Duncan, D. M., M.A. 83 Spence-street, Winnipeg, Canada.
1891. *Duncan, Sir John, J.P. 'South Wales Daily News' Office, Cardiff.
1896. *Dunkerley, Stanley, *D.Sc., M.Inst.C.E., Professor of Engineering in the Victoria University, Manchester.*
1876. ‡Dunnachie, James. 48 West Regent-street, Glasgow.
1884. ‡Dunnington, Professor F. P. University of Virginia, Charlottesville, Virginia, U.S.A.
1893. *Dunstan, M. J. R., Principal of the South-Eastern Agricultural College, Wye, Kent.
1891. ‡Dunstan, Mrs. South-Eastern Agricultural College, Wye, Kent.
1885. *Dunstan, Professor Wyndham, M.A., LL.D., F.R.S., V.P.C.S. (Pres. B, 1906; Council, 1905–08), Director of the Imperial Institute, S.W.
1905. §Dutton, C. L. O'Brien. High Commissioner's Office, Johannesburg.

Year of Election.

1895. *Dwerryhouse, Arthur R., D.Sc., F.G.S. Deraness, Deramore Park, Belfast.
1885. *Dyer, Henry, M.A., D.Sc. 8 Highburgh-terrace, Dowanhill, Glasgow.
1895. §Dymond, Thomas S., F.C.S. Savile Club, Piccadilly, W.
1905. *Dyson, F. W., M.A., F.R.S. (Council, 1905–), Astronomer Royal for Scotland and Professor of Practical Astronomy in the University of Edinburgh.

1905. ‡Earp, E. J. P.O. Box 538, Cape Town.
1899. ‡East, W. H. Municipal School of Art, Science, and Technology, Dover.
1909. *Easterbrook, C. C., M.A., M.D. Crichton Royal Institution, Dumfries.
1871. *Easton, Edward. (Pres. G, 1878; Council, 1879–81.) 22 Vincent-square, Westminster, S.W.
1893. *Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, E.C.
1906. *Ebbs, Mrs. A. B. Tuborg, Durham-avenue, Bromley, Kent.
1909. §Eccles, J. R. Gresham's School, Holt, Norfolk.
1903. ‡Eccles, W. H., D.Sc. 16 Worfield-street, Battersea, S.W.
1908. *Eddington, A. S., B.A., M.Sc. Royal Observatory, Greenwich, S.E.
1870. *Eddison, John Edwin, M.D., M.R.C.S. The Lodge, Adel, Leeds.
1858. *Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1884. *Edgell, Rev. R. Arnold, M.A. Beckley Rectory, East Sussex.
1887. §Edgeworth, F. Y., M.A., D.C.L., F.S.S. (Pres. F, 1889; Council, 1879–86, 1891–98), Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1870. *Edmonds, F. B. 6 Clement's Inn, W.C.
1883. ‡Edmonds, William. Wiscombe Park, Colyton, Devon.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, S.W.
1884. *Edmunds, James, M.D. 23 Sussex-square, Kemp Town, Brighton.
1901. *Edridge-Green, F. W., M.D., F.R.C.S. Hendon Grove, Hendon, N.W.
1899. §Edwards, E. J., Assoc.M.Inst.C.E. 290 Trinity-road, Wandsworth, S.W.
1903. ‡Edwards, Mrs. Emily. Norley Grange, 73 Leyland-road, Southport.
1903. ‡Edwards, Francis. Norley Grange, 73 Leyland-road, Southport.
1903. ‡Edwards, Miss Marion K. Norley Grange, 73 Leyland-road, Southport.
1901. ‡Eggar, W. D. Eton College, Windsor.
1909. §Eggertson, Arni. 120 Emily-street, Winnipeg, Canada.
1909. §Ehrenborg, G. B. Vancouver, B.C., Canada.
1907. *Elderton, W. Palin. 74 Mount Nod-road, Streatham, S.W.
1890. ‡Elford, Percy. St. John's College, Oxford.
1901. *Elles, Miss Gertrude L., D.Sc. Newnham College, Cambridge.
1904. ‡Elliot, Miss Agnes I. M. Newnham College, Cambridge.
1904. ‡Elliot, R. H. Clifton Park, Kelso, N.B.
1904. ‡*Elliot, T. R. B. Holme Park, Rotherfield, Sussex.*
1891. ‡Elliott, A. C., D.Sc., M.Inst.C.E., Professor of Engineering in University College, Cardiff. 2 Plasturton-avenue, Cardiff.
1905. ‡Elliott, C. C., M.D. Church-square, Cape Town.
1883. *Elliott, Edwin Bailey, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. 4 Bardwell-road, Oxford.

Year of Election.

Elliott, John Fogg. Elvet Hill, Durham.
1906. *Ellis, David, D.Sc., Ph.D. Technical College, Glasgow.
1875. *Ellis, H. D. 12 Gloucester-terrace, Hyde Park, W.
1906. §Ellis, Herbert. 120 Regent-road, Leicester.
1880. *Ellis, John Henry. (Local Sec. 1883.) 10 The Crescent, Plymouth.
1891. §Ellis, Miss M. A. 14 Wellington-square, Oxford.
1906. ‡Elmhirst, Charles E. (Local Sec. 1906.) 29 Mount-vale, York.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1869. *Enys, John Davies. Enys, Penryn, Cornwall.
1862. *Esson, William, M.A., F.R.S., F.R.A.S., Savilian Professor of Geometry in the University of Oxford. 13 Bradmore-road, Oxford.
1887. *Estcourt, Charles, F.I.C. 5 Seymour-grove, Old Trafford, Manchester.
1887 *Estcourt, P. A., F.C.S., F.I.C. 5 Seymour-grove, Old Trafford, Manchester.
1897. *Evans, Lady. Britwell, Berkhamsted, Herts.
1889. *Evans, A. H., M.A. 9 Harvey-road, Cambridge.
1905. ‡Evans, Mrs. A. H. 9 Harvey-road, Cambridge.
1870. *Evans, Arthur John, M.A., LL.D., F.R.S., F.S.A. (Pres. H, 1896.) Youlbury, Abingdon.
1908. §Evans, Rev. Henry, D.D., Commissioner of National Education, Ireland. Blackrock, Co. Dublin.
1887. *Evans, Mrs. Isabel. Hoghton Hall, Hoghton, near Preston.
1883. *Evans, Mrs. James C. Casewell Lodge, Llanwrtyd Wells, South Wales.
1885. *Evans, Percy Bagnall. The Spring, Kenilworth.
1905. ‡Evans, R. O. Ll. Broom Hall, Chwilog, R.S.O., Carnarvonshire.
1905. ‡Evans, T. H. 9 Harvey-road, Cambridge.
1905. ‡Evans, Thomas H. P.O. Box 1276, Johannesburg.
1865. *Evans, William. The Spring, Kenilworth.
1909. §Evans, W. Sanford, M.A. (Local Sec. 1909). 43 Edmonton-street, Winnipeg.
1903. ‡Evatt, E. J., M.B. 8 Kyveilog-street, Cardiff.
1871. ‡Eve, H. Weston, M.A. 37 Gordon-square, W.C.
1902. *Everett, Percy W. Oaklands, Elstree, Hertfordshire.
1872. ‡Eversley, Right Hon. Lord, F.R.S. (Pres. F, 1879; Council, 1878–80.) 18 Bryanston-square, W.
1883. ‡Eves, Miss Florence. Uxbridge.
1881. ‡Ewart, J. Cossar, M.D., F.R.S. (Pres. D, 1901), Professor of Natural History in the University of Edinburgh.
1874. ‡Ewart, Sir W. Quartus, Bart. (Local Sec. 1874.) Glenmachan, Belfast.
1876. *Ewing, James Alfred, C.B., M.A., LL.D., F.R.S., F.R.S.E., M.Inst.C.E. (Pres. G, 1906). Director of Naval Education, Admiralty, S.W. Froghole, Edenbridge, Kent.
1903. §Ewing, Peter, F.L.S. The Frond, Uddingston, Glasgow.
1884. *Eyerman, John, F.Z.S. Oakhurst, Easton, Pennsylvania, U.S.A.
1905. ‡Eyre, Dr. G. G. Claremont, Cape Colony.
Eyton, Charles. Hendred House, Abingdon.

1906. *Faber, George D., M.P. 14 Grosvenor-square, W.
1901. *Fairgrieve, M. McCallum. 115 Dalkeith-road, Edinburgh.
1865. *Fairley, Thomas, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.

Year of Election.

1908. ‡Falconer, Robert A., M.A. 44 Merrion-square, Dublin.
1896. §Falk, Herman John, M.A. Thorshill, West Kirby, Cheshire.
1902. §Fallaize, E. N., M.A. Vinchelez, Chase Court-gardens, Windmill-hill, Enfield.
1907. *Fantham, H. B., D.Sc. New Museums, Cambridge.
1898. ‡Faraday, Miss Ethel R., M.A. Ramsay Lodge, Levenshulme, near Manchester.
1902. §Faren, William. 11 Mount Charles, Belfast.
1892. *Farmer, J. Bretland, M.A., F.R.S., F.L.S. (Pres. K, 1907), Professor of Botany, Imperial College of Science, S.W.
1886. ‡Farncombe, Joseph, J.P. Saltwood, Spencer-road, Eastbourne.
1897. *Farnworth, Mrs. Ernest. Broadlands, Goldthorn Hill, Wolverhampton.
1904. ‡Farnworth, Miss Olive. Broadlands, Goldthorn Hill, Wolverhampton.
1885. *Farquharson, Mrs. R. F. O. Tillydrine, Kincardine O'Neil, N.B.
1905. ‡Farrar, Edward. P.O. Box 1242, Johannesburg.
1904. §Farrer, Sir William. 18 Upper Brook-street, W.
1903. §Faulkner, Joseph M. 13 Great Ducie-street, Strangeways, Manchester.
1890. *Fawcett, F. B. University College, Bristol
1906. §Fawcett, Henry Hargreave. 20 Margaret-street, Cavendish-square, W.
1900. ‡Fawcett, J. E., J.P. (Local Sec. 1900.) Low Royd, Apperley Bridge, Bradford.
1902. *Fawsitt, C. E., Ph.D. 9 Foremount-terrace, Dowanhill, Glasgow.
1909. *Fay, Charles Ryle, M.A. Christ's College, Cambridge.
1906. *Fearnsides, Edwin G., B.A., B.Sc. 56 Gore-road, South Hackney, E.
1901. *Fearnsides, W. G., M.A., F.G.S. Sidney Sussex College, Cambridge.
1905. §Feilden, Colonel H. W., C.B., F.G.S. Burwash, Sussex.
1900. *Fennell, William John. Deramore Drive, Belfast.
1904. ‡Fenton, H. J. H., M.A., F.R.S. 19 Brookside, Cambridge.
1906. ‡Ferguson, Allan. Cemetery Hotel, Newhall-lane, Preston.
1902. ‡*Ferguson, Godfrey W. (Local Sec. 1902.) Cluan, Donegall Park, Belfast.*
1871. *Ferguson, John, M.A., LL.D., F.R.S.E., F.S.A., F.C.S., Professor of Chemistry in the University of Glasgow.
1896. *Ferguson, Hon. John, C.M.G. Southfield House, Watford, Herts.
1901. ‡Ferguson, R. W. Municipal Technical School, the Gamble Institute, St. Helens, Lancashire.
1863. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1905. ‡*Ferrar, J. E. Sidney Sussex College, Cambridge.*
1905. *Ferrar, H. T. Survey Department, Giza, Egypt.
1873. ‡Ferrier, David, M.A., M.D., LL.D., F.R.S., Professor of Neuro-Pathology in King's College, London. 34 Cavendish-square, W.
1909. §Fetherstonhaugh, Professor Edward P., B.Sc. 119 Betourney-street, Winnipeg, Canada.
1882. §Fewings, James, B.A., B.Sc. King Edward VI. Grammar School, Southampton.
1897. ‡Field, George Wilton, Ph.D. Room 158, State House, Boston, Massachusetts, U.S.A.
1907. §Fields, Professor J. C. The University, Toronto, Canada.
1906. §Filon, L. N. G., D.Sc. Vega, Blenheim Park-road, Croydon.
1883. *Finch, Gerard B., M.A. Howes Close, Cambridge.

Year of Election.

1905. ‡Fincham, G. H. Hopewell, Invami, Cape Colony.
1905. §Findlay, Alexander, M.A., Ph.D., D.Sc., Lecturer on Physical Chemistry in the University of Birmingham.
1904. *Findlay, J. J., Ph.D., Professor of Education in the Victoria University, Manchester. Ruperra, Victoria Park, Manchester.
1902. ‡Finnegan, J., M.A., B.Sc. Kelvin House, Botanic-avenue, Belfast.
1902. ‡Fisher, J. R. Cranfield, Fortwilliam Park, Belfast.
1909. §Fisher, James, K.C. Trust and Loan Building, Winnipeg, Canada.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlton Rectory, near Cambridge.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1887. *Fison, Alfred H., D.Sc. 47 Dartmouth-road, Willesden Green, N.W.
1871. *FISON, Sir FREDERICK W., Bart., M.A., F.C.S. 64 Pont-street, S.W.
1883. ‡Fitch, Rev. J. J. 5 Chambres-road, Southport.
1885. *FITZGERALD, Professor MAURICE, B.A. (Local Sec. 1902.) 32 Eglantine-avenue, Belfast.
1894. ‡Fitzmaurice, Maurice, C.M.G., M.Inst.C.E. London County Council, Spring-gardens, S.W.
1888. *FITZPATRICK, Rev. THOMAS C., President of Queens' College, Cambridge.
1904. ‡Flather, J. H., M.A. Camden House, 90 Hills-road, Cambridge.
1908. §Flavelle, Miss Ruth E. 7 Alexandra House, St. Mary's-terrace, Paddington, W.
1904. §Fleming, James. 25 Kelvinside-terrace South, Glasgow.
1890. ‡*Fletcher, B. Morley.* 7 *Victoria-street, S.W.*
1892. ‡Fletcher, George, F.G.S. 55 Pembroke-road, Dublin.
1888. *FLETCHER, LAZARUS, M.A., F.R.S., F.G.S., F.C.S. (Pres. C, 1894), Director of the Natural History Museum, Cromwell-road, S.W. 35 Woodville-gardens, Ealing, W.
1908. *Fletcher, W. H. B. Aldwick Manor, Bognor, Sussex.
1901. ‡Flett, J. S., M.A., D.Sc., F.R.S.E. 28 Jermyn-street, S.W.
1906. *Fleure, H. J., D.Sc., Professor of Zoology and Geology in University College, Aberystwyth.
1905. *Flint, Rev. W., D.D. Houses of Parliament, Cape Town.
1889. ‡Flower, Lady. 26 Stanhope-gardens, S.W.
1905. ‡Flowers, Frank. United Buildings, Foxburgh, Johannesburg.
1890. *FLUX, A. W., M.A. Board of Trade, Gwydyr House, Whitehall, S.W.
1877. ‡Foale, William. The Croft, Madeira Park, Tunbridge Wells.
1903. ‡Foord-Kelcey, W., Professor of Mathematics in the Royal Military Academy, Woolwich. The Shrubbery, Shooter's Hill, S.E.
1906. §Forbes, Charles Mansfeldt. 1 Oriel-crescent, Scarborough.
1873. *FORBES, GEORGE, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 11 Little College-street, Westminster, S.W.
1883. ‡FORBES, HENRY O., LL.D., F.Z.S., Director of Museums for the Corporation of Liverpool. The Museum, Liverpool.
1905. §FORBES, Major W. LACHLAN, Sec. R. Scot. G. S. Synod Hall, Castle-terrace, Edinburgh.
1890. ‡FORD, J. RAWLINSON. (Local Sec. 1890.) Quarry Dene, Weetwood-lane, Leeds.
1875. *FORDHAM, Sir HERBERT GEORGE. Odsey, Ashwell, Baldock, Herts.
1909. §FORGET, The Hon. A. E. Regina, Saskatchewan, Canada.
1887. ‡FORREST, The Right Hon. Sir JOHN, G.C.M.G., F.R.G.S., F.G.S., Perth, Western Australia.

Year of Election.

1902. *Forster, M. O., Ph.D., D.Sc., F.R.S. Royal College of Science, S.W.
1883. ‡Forsyth, A. R., M.A., D.Sc., F.R.S. (Pres. A, 1897, 1905; Council, 1907–09), Sadlerian Professor of Pure Mathematics in the University of Cambridge. Trinity College, Cambridge.
1857. *Foster, George Carey, B.A., LL.D., D.Sc., F.R.S. (General Treasurer, 1898–1904; Pres. A, 1877; Council, 1871–76, 1877–82). Ladywalk, Rickmansworth.
1908. *Foster, John Arnold. 11 Hills-place, Oxford Circus, W.
1901. §Foster, T. Gregory, Ph.D., Principal of University College, London. Chester-road, Northwood, Middlesex.
1903. ‡Fourcade, H. G. P.O., Storms River, Humansdorp, Cape Colony.
1905. §Fowlds, Hiram. 65 Devonshire-street, Keighley, Yorkshire.
1909. §Fowlds, Mrs. 65 Devonshire-street, Keighley, Yorkshire.
1909. §Fowler, Colonel C. A., D.S.O. Care of Messrs. Thomas Cook & Son, Ludgate Circus, E.C.
1909. §Fowler, Mrs. Cecily. Care of Messrs. Thomas Cook & Son, Ludgate-circus, E.C.
1906. §Fowler, Oliver H., M.R.C.S. Ashcroft House, Cirencester.
1883. *Fox, Charles. The Pynes, Warlingham-on-the-Hill, Surrey.
1883. ‡Fox, Sir Charles Douglas, M.Inst.C.E. (Pres. G, 1896.) Cross Keys House, 56 Moorgate-street, E.C.
1904. *Fox, Charles J. J., B.Sc., Ph.D. 33 Ashley-road, Crouch Hill, N.
1904. §Fox, F. Douglas, M.A., M.Inst.C.E. 19 The Square, Kensington, W.
1905. ‡Fox, Mrs. F. Douglas. 19 The Square, Kensington, W.
1883. ‡Fox, Howard, F.G.S. Rosehill, Falmouth.
1847. *Fox, Joseph Hoyland. The Clive, Wellington, Somerset.
1900. *Fox, Thomas. Old Way House, Wellington, Somerset.
1909. *Fox, Wilson Lloyd. Carmino, Falmouth.
1908. §Foxley, Miss Barbara, M.A. 12 Lime-grove, Manchester.
1881. *Foxwell, Herbert S., M.A., F.S.S. (Council, 1894–97), Professor of Political Economy in University College, London. St. John's College, Cambridge.
1907. §Fraine, Miss Ethel de. Whitelands College, King's-road, Chelsea, S.W.
1905. ‡Frames, Henry J. Talana, St. Patrick's-avenue, Parktown, Johannesburg.
1905. ‡Frames, Mrs. Talana, St. Patrick's-avenue, Parktown, Johannesburg.
1905. ‡Francke, M. P.O. Box 1156, Johannesburg.
1887. *Frankland, Percy F., Ph.D., B.Sc., F.R.S. (Pres. B, 1901), Professor of Chemistry in the University of Birmingham.
1895. §Fraser, Alexander. 63 Church-street, Inverness.
1882. *Fraser, Alexander, M.B., Professor of Anatomy in the Royal College of Surgeons, Dublin. 18 Northbrook-road, Dublin.
1908. ‡Fraser, Mrs. Alexander. 18 Northbrook-road, Dublin.
1885. ‡Fraser, Angus, M.A., M.D., F.C.S. (Local Sec. 1885). 232 Union-street, Aberdeen.
1906. *Fraser, Miss Helen C. I., D.Sc., F.L.S. University College, Nottingham.
1871. ‡Fraser, Sir Thomas R., M.D., F.R.S., F.R.S.E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1884. *Fremantle, The Hon. Sir C. W., K.C.B. (Pres. F, 1892; Council, 1897–1903.) 4 Lower Sloane-street, S.W.
1906. §French, Fleet-Surgeon A. M. Langley, Beaufort-road, Kingston-on-Thames.

Year of
Election.

1909. §French, Mrs. Harriet A. Suite E, Grine's-block, Portage-avenue, Winnipeg, Canada.
1905. ‡French, Sir Somerset R., K.C.M.G. 100 Victoria-street, S.W.
1886. ‡Freshfield, Douglas W., F.R.G.S. (Pres. E, 1904.) 1 Airlie-gardens, Campden Hill, W.
1901. ‡Frew, William, Ph.D. King James-place, Perth.
1887. *Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1906. §Fritsch, Dr. F. E. 77 Chatsworth-road, Brondesbury, N.W.
1892. *Frost, Edmund, M.D. Chesterfield-road, Eastbourne.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1887. *Frost, Robert, B.Sc. 55 Kensington-court, W.
1898. ‡Fry, The Right Hon. Sir Edward, D.C.L., LL.D., F.R.S., F.S.A. Failand House, Failand, near Bristol.
1905. ‡Fry, H. P.O. Box 46, Johannesburg.
1875. *Fry, Joseph Storrs. 16 Upper Belgrave-road, Clifton, Bristol.
1908. ‡Fry, M. W. J., M.A. 39 Trinity College, Dublin.
1905. *Fry, William, J.P., F.R.G.S. Wilton House, Merrion-road, Dublin.
1898. ‡Fryer, Alfred C., Ph.D. 13 Eaton-crescent, Clifton, Bristol.
1872. *Fuller, Rev. A. 7 Sydenham-hill, Sydenham, S.E.
1869. ‡Fuller, G., M.Inst.C.E. (Local Sec. 1874.) 71 Lexham-gardens, Kensington, W.

1863. *Gainsford, W. D. Skendleby Hall, Spilsby
1906. §Gajjar, Professor T. K., M.A. Techno-Chemical Laboratory, near Girgaum Tram Terminus, Bombay.
1885. *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
1875. ‡Galloway, W. Cardiff.
1887. *Galloway, W. J. The Cottage, Seymour-grove, Old Trafford, Manchester.
1905. ‡Galpin, Ernest E. Bank of Africa, Queenstown, Cape Colony.
1860. *Galton, Sir Francis, M.A., D.C.L., D.Sc., F.R.S., F.R.G.S. (Gen. Sec. 1863–68; Pres. E, 1862, 1872; Pres. H, 1885; Council, 1860–63.) 42 Rutland-gate, Knightsbridge, S.W.
1888. *Gamble, J. Sykes, C.I.E., M.A., F.R.S., F.L.S. Highfield, East Liss, Hants.
1899. *Garcke, E. Ditton House, near Maidenhead.
1898. ‡Garde, Rev. C. L. Skenfrith Vicarage, near Monmouth.
1905. ‡Gardiner, J. H. 59 Wroughton-road, Balham, S.W.
1900. ‡Gardiner, J. Stanley, M.A., F.R.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Gonville and Caius College, Cambridge.
1887. ‡Gardiner, Walter, M.A., D.Sc., F.R.S. St. Awdreys, Hills-road, Cambridge.
1882. *Gardner, H. Dent, F.R.G.S. Fairmead, 46 The Goffs, Eastbourne.
1905. ‡Garlick, John. Thornibrae, Green Point, Cape Town.
1905. ‡Garlick, R. C. Thornibrae, Green Point, Cape Town.
1887. *Garnett, Jeremiah. The Grange, Bromley Cross, near Bolton, Lancashire.
1882. ‡Garnett, William, D.C.L. London County Council, Victoria Embankment, W.C.
1883. ‡Garson, J. G., M.D. (Assist. Gen. Sec. 1902–04.) Moorcote, Eversley, Winchfield.
1903. ‡Garstang, A. H. 20 Roe-lane, Southport.
1903. *Garstang, T. James, M.A. Bedale's School, Petersfield, Hampshire.

Year of Election.

1894. *GARSTANG, WALTER, M.A., D.Sc., F.Z.S., Professor of Zoology in the University of Leeds.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1905. ‡Garthwaite, E. H. B. S. A. Co., Bulawayo, South Africa.
1889. ‡GARWOOD, Professor E. J., M.A., F.G.S. University College, Gower-street, W.C.
1905. ‡Gaskell, Miss C. J. The Uplands, Great Shelford, Cambridge.
1905. ‡Gaskell, Miss M. A. The Uplands, Great Shelford, Cambridge.
1896. *GASKELL, WALTER HOLBROOK, M.A., M.D., LL.D., F.R.S. (Pres. I, 1896; Council, 1898–1901.) The Uplands, Great Shelford, Cambridge.
1906. §Gaster, Leon. 32 Victoria-street, S.W.
1905. ‡Gaughren, Right Rev. Dr. M. Dutoitspan-road, Kimberley.
1906. ‡Gavey, E. H. Myddelton, M.R.C.S. Stanton Prior, Meads, Eastbourne.
1905. *Gearon, Miss Susan. 55 Buckleigh-road, Streatham Common, S.W.
1867. ‡GEIKIE, Sir ARCHIBALD, K.C.B., LL.D., D.Sc., Pres.R.S., F.R.S.E., F.G.S. (PRESIDENT, 1892; Pres. C, 1867, 1871, 1899; Council, 1888–1891.) Shepherd's Down, Haslemere, Surrey.
1871. ‡GEIKIE, JAMES, LL.D., D.C.L., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1889; Pres. E, 1892). Murchison Professor of Geology and Mineralogy in the University of Edinburgh. Kilmorie, Colinton-road, Edinburgh.
1898. ‡Gemmill, James F., M.A., M.D. 21 Endsleigh-gardens, Partick-hill, Glasgow.
1882. *GENESE, R. W., M.A., Professor of Mathematics in University College, Aberystwyth.
1905. ‡Gentleman, Miss A. A. 9 Abercromby-place, Stirling.
1875. *George, Rev. Hereford Brooke, M.A., F.R.G.S. Holywell Lodge, Oxford.
1902. *Gepp, Antony, M.A., F.L.S. British Museum (Natural History), Cromwell-road, S.W.
1899. *Gepp, Mrs. A. 7 Cumberland-road, Kew.
1884. *Gerrans, Henry T., M.A. 20 St. John-street, Oxford.
1909. §GIBBONS, W. M., M.A. (Local Sec. 1910.) The University, Sheffield.
1905. §Gibbs, Miss Lilian S., F.L.S. 22 South-street, Thurloe-square, S.W.
1902. ‡Gibson, Andrew. 14 Cliftonville-avenue, Belfast.
1901. §Gibson, Professor George A., M.A. 8 Sandyford-place, Glasgow.
1876. *Gibson, George Alexander, M.D., D.Sc., LL.D., F.R.S.E. 3 Drumsheugh-gardens, Edinburgh.
1904. *Gibson, Mrs. Margaret D., LL.D. Castle Brae, Chesterton-lane, Cambridge.
1896. ‡GIBSON, R. J. HARVEY, M.A., F.R.S.E., Professor of Botany in the University of Liverpool.
1889. *Gibson, T. G. Lesbury House, Lesbury, R.S.O., Northumberland.
1893. ‡Gibson, Walcot, F.G.S. 28 Jermyn-street, S.W.
1887. *GIFFEN, Sir ROBERT, K.C.B., LL.D., F.R.S., V.P.S.S. (Pres. F, 1887, 1901.) Chanctonbury, Hayward's Heath.
1898. *Gifford, J. William. Oaklands, Chard.
1883. §Gilbert, Lady. Park View, Englefield Green, Surrey.
1884. *Gilbert, Philip H. 63 Tupper-street, Montreal, Canada.
1895. ‡GILCHRIST, J. D. F., M.A., Ph.D., B.Sc., F.L.S. Marine Biologist's Office, Department of Agriculture, Cape Town.

Year of Election.

1896. *GILCHRIST, PERCY C., F.R.S., M.Inst.C.E. Reform Club, Pall Mall, S.W.
1878. ‡Giles, Oliver. Brynteg, The Crescent, Bromsgrove.
1871. *GILL, Sir DAVID, K.C.B., LL.D., D.Sc., F.R.S., Hon.F.R.S.E. (PRESIDENT, 1907.) 34 De Vere-gardens, Kensington, W.
1902. ‡Gill, James F. 72 Strand-road, Bootle, Liverpool.
1908. ‡Gill, T. P. Department of Agriculture and Technical Instruction for Ireland, Dublin.
1892. *Gilmour, Matthew A. B., F.Z.S. Saffronhall House, Windmill-road, Hamilton, N.B.
1907. §Gilmour, S. C. 3 Vernon-chambers, Southampton-row, W.C.
1908. ‡Gilmour, T. L. 1 St. John's Wood Park, N.W.
1893. *Gimingham, Edward. Croyland, Clapton Common, N.
1904. ‡GINN, S. R., D.L. (Local Sec. 1904.) Brookfield, Trumpington-road, Cambridge.
1900. ‡*Ginsburg, Benedict W., M.A., LL.D. Cookham, Berks.*
1884. ‡Girdwood, G. P., M.D. 28 Beaver Hall-terrace, Montreal, Canada.
1886. *Gisborne, Hartley, M.Can.S.C.E. Caragana Lodge, Ladysmith, Vancouver Island, Canada.
1883. *Gladstone, Miss. 19 Chepstow-villas, Bayswater, W.
1871. *GLAISHER, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. (Pres. A, 1890; Council, 1878–86.) Trinity College, Cambridge.
1880. *GLANTAWE, Right Hon. Lord. The Grange, Swansea.
1881. *GLAZEBROOK, R. T., M.A., D.Sc., F.R.S. (Pres. A, 1893; Council, 1890–94, 1905–), Director of the National Physical Laboratory. Bushy House, Teddington, Middlesex.
1881. *Gleadow, Frederic. 38 Ladbroke-grove, W.
Glover, Thomas. 124 Manchester-road, Southport.
1878. *Godlee, J. Lister. Wakes Colne Place, Essex.
1880. ‡GODMAN, F. DU CANE, D.C.L., F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, W.
1879. ‡GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.R.G.S., F.Z.S. (Pres. E, 1883.) Nore, Godalming.
1878. ‡GOFF, JAMES. (Local Sec. 1878.) 29 Lower Leeson-street, Dublin.
1908. *GOLD, ERNEST, M.A. 3 Devana-terrace, Cambridge.
1906. ‡GOLDIE, Sir GEORGE D. T., K.C.M.G., D.C.L., F.R.S. (Pres. E, 1906; Council, 1906–07.) 44 Rutland-gate, S.W.
1898. ‡Goldney, F. Bennett, F.S.A. Goodnestone Park, Dover.
1899. ‡GOMME, G. L., F.S.A. 24 Dorset-square, N.W.
1890. *GONNER, E. C. K., M.A. (Pres. F, 1897), Professor of Political Economy in the University of Liverpool.
1909. §Goodair, Thomas. 303 Kennedy-street, Winnipeg, Canada.
1907. §Goodrich, E. S., M.A., F.R.S., F.L.S. Merton College, Oxford.
1884. *Goodridge, Richard E. W. Coleraine, Minnesota, U.S.A.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1905. ‡GOOLD-ADAMS, Major Sir H. J., G.C.M.G., C.B. Government House, Bloemfontein, South Africa.
1909. §Gordon, Rev. Charles W. 567 Broadway, Winnipeg, Canada.
1909. §Gordon, J. T. 147 Hargrave-street, Winnipeg, Canada.
1909. §Gordon, Mrs. J. T. 147 Hargrave-street, Winnipeg, Canada.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's-mansions, Westminster, S.W.
1893. ‡Gordon, Mrs. M. M. Ogilvie, D.Sc. 1 Rubislaw-terrace, Aberdeen.
1901. ‡GORST, Right Hon. Sir JOHN E., M.A., K.C., M.P., F.R.S. (Pres. L, 1901.) 21 Victoria-square, S.W.

Year of
Election.

1875. *Gotch, Francis, M.A., D.Sc., F.R.S. (Pres. I, 1906; Council, 1901–07), Professor of Physiology in the University of Oxford. The Lawn, Banbury-road, Oxford.
1881. ‡Gough, Rev. Thomas, B.Sc. King Edward's School, Retford.
1901. ‡Gourlay, Robert. Glasgow.
1901. ‡Gow, Leonard. Hayston, Kelvinside, Glasgow.
1876. ‡Gow, Robert. Cairndowan, Dowanhill-gardens, Glasgow.
1883. ‡Gow, Mrs. Cairndowan, Dowanhill-gardens, Glasgow.
1873. ‡Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1908. §Grabham, G. W., M.A., F.G.S. P.O. Box 178, Khartoum, Sudan.
1886. ‡Grabham, Michael C., M.D. Madeira.
1909. §Grace, J. H., M.A., F.R.S. Peterhouse, Cambridge.
1909. §Graham, Herbert W. 329 Kennedy-street, Winnipeg, Canada.
1902. *Graham, William, M.D. District Lunatic Asylum, Belfast.
1875. ‡Grahame, James. (Local Sec. 1876.) Care of Messrs. Grahame, Crums, & Connal, 34 West George-street, Glasgow.
1904. §Gramont, Comte Arnaud de, D.Sc. 179 rue de l'Université, Paris.
1896. ‡Grant, Sir James, K.C.M.G. Ottawa, Canada.
1908. *Grant, W. L. 10 Park-terrace, Oxford.
1905. ‡Graumann, Harry. P.O. Box 2115, Johannesburg.
1890. ‡Gray, Andrew, M.A., LL.D., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Glasgow.
1905. ‡Gray, C. J. P.O. Box 208, Pietermaritzburg, South Africa.
1864. *Gray, Rev. Canon Charles. West Retford Rectory, Retford.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1903. §Gray, Ernest, M.A. 99 Grosvenor-road, S.W.
1904. ‡Gray, Rev. H. B., D.D. (Pres. L, 1909.) The College, Bradfield, Berkshire.
1892. *Gray, James Hunter, M.A., B.Sc. 3 Crown Office-row, Temple, E.C.
1904. ‡*Gray, J. Marfarlane.* 4 *Ladbroke-crescent, W.*
1892. §Gray, John, B.Sc. 9 Park-hill, Clapham Park, S.W.
1887. ‡Gray, Joseph W., F.G.S. St. Elmo, Leckhampton-road, Cheltenham.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1886. *Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1901. ‡Gray, R. W. 7 Orme-court, Bayswater, W.
1873. ‡Gray, William, M.R.I.A. Glenburn Park, Belfast.
*Gray, Colonel William. Farley Hall, near Reading.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1893. *Greaves, Mrs. Elizabeth. Station-street, Nottingham.
1905. ‡Green, A. F. Sea Point, Cape Colony.
1904. *Green, Professor A. G., M.Sc. The Old Gardens, Cardigan-road, Headingley, Leeds.
1904. §Green, F. W. 5 Wordsworth-grove, Cambridge.
1906. §Green, Professor J. A., M.A. The University, Sheffield.
1888. §Green, J. Reynolds, M.A., D.Sc., F.R.S., F.L.S. (Pres. K, 1902), Professor of Botany to the Pharmaceutical Society of Great Britain. Downing College, Cambridge.
1903. ‡Green, W. J. 76 Alexandra-road, N.W.
1908. ‡Green, Rev. William Spotswood, C.B., F.R.G.S. 5 Cowper-villas, Cowper-road, Dublin.
1909. §Greenfield, Joseph. P.O. Box 2935, Winnipeg, Canada.
1882. ‡Greenhill, Sir A. G., M.A., F.R.S., Professor of Mathematics in the Royal Artillery College, Woolwich. 1 Staple Inn, W.C.
1905. ‡Greenhill, Henry H. P.O. Box 172, Bloemfontein, South Africa.
1905. ‡Greenhill, William. 6a George-street, Edinburgh.

Year of Election.

1891. *GREENLY, EDWARD, F.G.S. Achnashean, near Bangor, North Wales.
1906. ‡Greenwood, Hamar, M.P. National Liberal Club, Whitehall-place, S.W.
1894. *GREGORY, J. WALTER, D.Sc., F.R.S., F.G.S. (Pres. C, 1907), Professor of Geology in the University of Glasgow.
1896. *GREGORY, Professor R. A., F.R.A.S. Dell Quay House, near Chichester.
1904. *Gregory, R. P., M.A. 156 Chesterton-road, Cambridge.
1881. ‡Gregson, William, F.G.S. 106 Victoria-road, Darlington.
1836. Griffin, S. F. Albion Tin Works, York-road, N.
1894. *Griffith, C. L. T., Assoc.M.Inst.C.E. Municipal Offices, Madras.
1908. §Griffith, John P. Rathmines Castle, Rathmines, Dublin.
1884. ‡GRIFFITHS, E. H., M.A., D.Sc., F.R.S. (Pres. A, 1906), Principal of University College, Cardiff.
1884. ‡Griffiths, Mrs. University College, Cardiff.
1847. ‡Griffiths, Thomas. The Elms, Harborne-road, Edgbaston, Birmingham.
1903. ‡Griffiths, Thomas, J.P. 101 Manchester-road, Southport.
1888. *Grimshaw, James Walter, M.Inst.C.E. St Stephen's Club, Westminster, S.W.
1894. ‡GROOM, Professor P., M.A., F.L.S. Hollywood, Egham, Surrey.
1894. ‡Groom, T. T., M.A., D.Sc., F.G.S., Professor of Geology in the University of Birmingham.
1909. *Grossman, Edward L., M.D. 35 Avenide de San Francisco, Mexico City, Mexico.
1896. ‡Grossmann, Dr. Karl. 70 Rodney-street, Liverpool.
1904. ‡Grosvenor, G. H. New College, Oxford.
1869. ‡GRUBB, Sir HOWARD, F.R.S., F.R.A.S. Rockdale, Orwell-road, Rathgar, Dublin.
1897. ‡Grünbaum, A. S., M.A., M.D. School of Medicine, Leeds.
1887. ‡GUILLEMARD, F. H. H., M.A., M.D. The Mill House, Trumpington, Cambridge.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1905. *Gunn, Donald. Royal Societies Club, St. James's-street, S.W.
1909. §Gunne, J. R., M.D. Kenora, Ontario, Canada.
1909. §Gunne, W. J., M.D. Kenora, Ontario, Canada.
1866. ‡GÜNTHER, ALBERT C. L. G., M.A., M.D., Ph.D., F.R.S., F.L.S., F.Z.S. (Pres. D, 1880.) 22 Lichfield-road, Kew, Surrey.
1894. ‡Günther, R. T. Magdalen College, Oxford.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1904. §Gurney, Eustace. Sprowston Hall, Norwich.
1902. *Gurney, Robert. Ingham Old Hall, Stalham, Norfolk.
1904. §Guttmann, Professor Leo F., Ph.D. Queen's University, Kingston, Canada.

1905. ‡Hacker, Rev. W. J. Edendale, Pietermaritzburg, South Africa.
1908. *Hackett, Felix E. Royal College of Science, Dublin.
1881. *HADDON, ALFRED CORT, M.A., D.Sc., F.R.S., F.Z.S. (Pres. H, 1902, 1905; Council, 1902–08.) Inisfail, Hills-road, Cambridge.
1905. ‡Haddon, Miss. Inisfail, Hills-road, Cambridge.
1888. *Hadfield, Sir R. A., M.Inst.C.E. Parkhead House, Sheffield.
1905. ‡Hahn, Professor P. D., M.A., Ph.D. York House, Gardens, Cape Town.
1906. ‡Hake, George W. Oxford, Ohio, U.S.A.

Year of Election.

1894. ‡HALDANE, JOHN SCOTT, M.A., M.D., F.R.S. (Pres. I, 1908), Reader in Physiology in the University of Oxford. Jesus College, Oxford.
1899. ‡HALL, A. D., M.A., F.R.S. (Council, 1908–), Director of the Rothamsted Experimental Station, Harpenden, Herts.
1909. §Hall, Archibald A., M.Sc., Ph.D. Armstrong College, Newcastle-on-Tyne.
1903. ‡HALL, E. MARSHALL, K.C. 75 Cambridge-terrace, W.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1883. *Hall, Miss Emily. 63 Belmont-street, Southport.
1854. *HALL, HUGH FERGIE, F.G.S. Cissbury Court, West Worthing, Sussex.
1899. ‡Hall, John, M.D. National Bank of Scotland, 37 Nicholas-lane, E.C.
1884. §Hall, Thomas Proctor, M.D. 1301 Davie-street, Vancouver, B.C., Canada.
1908. *Hall, Wilfred, Assoc.M.Inst.C.E. 9 Prior's-terrace, Tynemouth, Northumberland.
1891. *Hallett, George. Cranford, Victoria-square, Penarth.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1888. §HALLIBURTON, W. D., M.D., LL.D., F.R.S. (Pres. I, 1902 ; Council, 1897–1903), Professor of Physiology in King's College, London Church Cottage, 17 Marylebone-road, N.W.
1905. ‡Halliburton, Mrs. Church Cottage, 17 Marylebone-road, N.W.
1904. *Hallidie, A. H. S. Avondale, Chesterfield-road, Eastbourne.
1908. ‡Hallitt, Mrs. Steeple Grange, Wirksworth.
1908. *Hamel, Egbert Alexander de. Middleton Hall, Tamworth.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1904. *Hamel de Manin, Anna Countess de. 35 Circus-road, N.W.
1906. ‡Hamill, John Molyneux, M.A., M.B. 14 South-parade, Chiswick.
1906. ‡Hamilton, Charles I. 88 Twyford-avenue, Acton.
1909. §Hamilton, F. C. Bank of Hamilton-chambers, Winnipeg, Canada.
1902. ‡HAMILTON, Rev. T., D.D. Queen's College, Belfast.
1909. §Hamilton, T. Glen, M.D. 264 Renton-avenue, Winnipeg, Canada.
1905. ‡Hammersley-Heenan, R. H., M.Inst.C.E. Harbour Board Offices, Cape Town.
1905. ‡Hammond, Miss Edith. High Dene, Woldingham, Surrey.
1881. *HAMMOND, ROBERT, M.Inst.C.E. 64 Victoria-street, Westminster, S.W.
1899. *Hanbury, Daniel. Lenqua da Cà, Alassio, Italy.
1878. §Hance, E. M. Care of J. Hope Smith, Esq., 3 Leman-street, E.C.
1909. §Hancock, C. B. Manitoba Government Telephones, Winnipeg, Canada.
1905. *Hancock, Strangman. Plas Uchaf, Abergele, North Wales.
1890. ‡*Hankin, Ernest Hanbury. St. John's College, Cambridge.*
1906. §Hanson, David. Salterlee, Halifax, Yorkshire.
1904. §Hanson, E. K. Woodthorpe, Royston Park-road, Hatch End, Middlesex.
1902. ‡Harbison, Adam, B.A. 5 Ravenhill-terrace, Ravenhill-road, Belfast.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., D.Sc., F.R.S., V.P.C.S. (GEN. SEC. 1883–97 ; Pres. B, 1875 ; Council, 1881–83.) St. Clare, Ryde, Isle of Wight.
1909. §Harcourt, George. Department of Agriculture, Edmonton, Alta, Canada.
1886. *Hardcastle, Colonel Basil W., F.S.S. 12 Gainsborough-gardens, Hampstead, N.W.
1902. **Hardcastle, Miss Frances.* 25 *Boundary-road, N.W.*

Year of
Election.

1903. *Hardcastle, J. Alfred. The Dial House, Crowthorne, Berkshire.
1892. *Harden, Arthur, Ph.D., M.Sc. Lister Institute of Preventive Medicine, Chelsea-gardens, Grosvenor-road, S.W.
1905. ‡Hardie, Miss Mabel, M.B. High-lane, *via* Stockport.
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1894. ‡Hardman, S. C. 120 Lord-street, Southport.
1909. §Hardy, W. B., M.A., F.R.S. Gonville and Caius College, Cambridge.
1883. ‡*Hargreaves, Miss H. M. 69 Alexandra-road, Southport.*
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1890. *Harker, Alfred, M.A., F.R.S., F.G.S. St. John's College, Cambridge.
1896. ‡Harker, Dr. John Allen. National Physical Laboratory, Bushy House, Teddington.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1905. ‡Harland, H. C. P.O. Box 1024, Johannesburg.
1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton.
1883. *Harley, Miss Clara. Rosslyn, Westbourne-road, Forest-hill, S.E.
1862. *Harley, Rev. Robert, M.A., F.R.S., F.R.A.S. Rosslyn, Westbourne-road, Forest-hill, S.E.
1868. *Harmer, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *Harmer, Sidney F., M.A., Sc.D., F.R.S. (Pres. D, 1908.) Keeper of the Department of Zoology, British Museum (Natural History), Cromwell-road, S.W.
1906. ‡Harper, J. B. 16 St. George's-place, York.
1842. *Harris, G. W. Millicent, South Australia.
1889. ‡Harris, H. Graham, M.Inst.C.E. 5 Great George-street, Westminster, S.W.
1909. §Harris, J. W. Civic Offices, Winnipeg.
1903. ‡Harris, Robert, M.B. Queen's-road, Southport.
1904. ‡Harrison, Frank L. The Grammar School, Soham, Cambridgeshire.
1904. ‡Harrison, H. Spencer. The Horniman Museum, Forest-hill, S.E.
1892. ‡Harrison, John. (Local Sec. 1892.) Rockville, Napier-road, Edinburgh.
1870. ‡Harrison, Reginald, F.R.C.S. (Local Sec. 1870.) 6 Lower Berkeley-street, Portman-square, W.
1892. ‡Harrison, Rev. S. N. Ramsey, Isle of Man.
1901. *Harrison, W. E. 15 Lansdowne-road, Handsworth, Staffordshire.
1885. ‡Hart, Colonel C. J. (Local Sec. 1886.) Highfield Gate, Edgbaston, Birmingham.
1909. §Hart, John A. 120 Emily-street, Winnipeg, Canada.
1876. *Hart, Thomas. Brooklands, Blackburn.
1903. *Hart, Thomas Clifford. Brooklands, Blackburn.
1907. §Hart, W. E. Kilderry, near Londonderry.
1893. *Hartland, E. Sidney, F.S.A. (Pres. H, 1906; Council, 1906– .) Highgarth, Gloucester.
1905. ‡Hartland, Miss. Highgarth, Gloucester.
1871. *Hartley, Walter Noel, D.Sc., F.R.S., F.R.S.E., F.C.S. (Pres. B, 1903), Professor of Chemistry in the Royal College of Science, Dublin. 10 Elgin-road, Dublin.
1886. *Hartog, Professor M. M., D.Sc. Queen's College, Cork.
1887. ‡Hartog, P. J., B.Sc. University of London, South Kensington, S.W.
1905. ‡Harvey-Hogan, J. P.O. Box 1277, Johannesburg.
1885. §Harvie-Brown, J. A. Dunipace, Larbert, N.B.

Year of Election.

1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
1893. §Haslam, Lewis. 44 Evelyn-gardens, S.W.
1903. *Hastie, Miss J. A. Care of Messrs. Street & Co., 30 Cornhill, E.C.
1903. §Hastie, William. 20 Elswick-row, Newcastle-on-Tyne.
1904. ‡HASTINGS, G. 15 Oak-lane, Bradford, Yorkshire.
1875. *HASTINGS, G. W. (Pres. F, 1880.) Chapel House, Chipping Norton.
1903. ‡Hastings, W. G. W. 2 Halsey-street, Cadogan-gardens, S.W.
1889. ‡HATCH, F. H., Ph.D., F.G.S. Cowley Place, Cowley, Middlesex.
1903. ‡Hathaway, Herbert G. 45 High-street, Bridgnorth, Salop.
1904. *Haughton, W. T. H. The Highlands, Great Barford, St. Neots.
1908. §Havelock, T. H. St. John's College, Cambridge.
1904. ‡Havilland, Hugh de. Eton College, Windsor.
1887. *Hawkins, William. Earlston House, Broughton Park, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, S.W.
1864. *HAWKSHAW, JOHN CLARKE, M.A., M.Inst.C.E., F.G.S. (Council, 1881–87.) 22 Down-street, W., and 33 Great George-street, S.W.
1897. §HAWKSLEY, CHARLES, M.Inst.C.E., F.G.S. (Pres. G, 1903; Council, 1902–09.) Caxton House (West Block), Westminster, S.W.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1861. *HAY, Admiral the Right Hon. Sir JOHN C. D., Bart., G.C.B., D.C.L., F.R.S. 108 St. George's-square, S.W.
1885. *HAYCRAFT, JOHN BERRY, M.D., B.Sc., F.R.S.E., Professor of Physiology in University College, Cardiff.
1900. §Hayden, H. H., B.A., F.G.S. Geological Survey, Calcutta, India.
1903. *Haydock, Arthur. 197 Preston New-road, Blackburn.
1903. ‡*Hayward, Joseph William, M.Sc. 29 Deodar-road, Putney, S.W.*
1896. *Haywood, Lieut.-Colonel A. G. Rearsby, Merrilocks-road, Blundellsands.
1879. *Hazelhurst, George S. The Grange, Rockferry.
1909. §Heaman, J. A., B.Sc. Suite 20, Moxam-court, Winnipeg, Canada.
1883. ‡Heape, Joseph R. Glebe House, Rochdale.
1882. *Heape, Walter, M.A., F.R.S. Greyfriars, Southwold, Suffolk.
1909. §Heard, Mrs. Sophie, M.B., Ch.B. Care of Messrs. Davidson & Garden, 12 Dee-street, Aberdeen.
1908. §Heath, J. St. George, B.A. Woodbrooke Settlement, Selly Oak, near Birmingham.
1902. ‡Heath, J. W. Royal Institution, Albemarle-street, W.
1909. §Heathcote, F. C. C. Broadway, Winnipeg, Canada.
1902. ‡Heathorn, Captain T. B., R.A. 10 Wilton-place, Knightsbridge, S.W.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1892. *HEATON, WILLIAM H., M.A. (Local Sec. 1893), Professor of Physics in University College, Nottingham.
1889. *Heaviside, Arthur West, I.S.O. 12 Tring-avenue, Ealing, W.
1888. *Heawood, Edward, M.A. Briarfield, Church-hill, Merstham, Surrey.
1888. *Heawood, Percy J., Lecturer in Mathematics in Durham University. 41 Old Elvet, Durham.
1887. *HEDGES, KILLINGWORTH, M.Inst.C.E. 10 Cranley-place, South Kensington, S.W.
1881. *HELE-SHAW, H. S., LL.D., F.R.S., M.Inst.C.E. 64 Victoria-street, S.W.
1901. *HELLER, W. M., B.Sc. 40 Upper Sackville-street, Dublin.
1905. ‡Hellman, Hugo. Rand Club, Johannesburg.
1887. §Hembry, Frederick William, F.R.M.S. Langford, Sidcup, Kent.
1908. ‡Hemmy, Professor A. S., B.A., M.Sc. Care of Dr. Davidson, Clavell House, Belvedere, Kent.

Year of Election.

1899. ‡Hemsalech, G. A., D.Sc. The Owens College, Manchester.
1901. ‡Henderson, Rev. Andrew, LL.D. Castle Head, Paisley.
1905. *Henderson, Andrew. 17 Belhaven-terrace, Glasgow.
1905. *Henderson, Miss Catharine. 17 Belhaven-terrace, Glasgow.
1891. *HENDERSON, G. G., D.Sc., M.A., F.I.C., Professor of Chemistry in the Glasgow and West of Scotland Technical College, Glasgow.
1905. §Henderson, Mrs. Technical College, Glasgow.
1907. §Henderson, H. F. Felday, Morland-avenue, Leicester.
1906. ‡Henderson, J. B., D.Sc., Professor of Applied Mechanics in the Royal Naval College, Greenwich, S.E.
1909. §Henderson, Veylien E. Medical Building, The University, Toronto, Canada.
1909. §Henderson, W. G. Louise Bridge, Winnipeg, Canada.
1880. *Henderson, Vice-Admiral W. H., R.N. 12 Vicarage-gardens, Campden Hill, W.
1904. *Hendrick, James. Marischal College, Aberdeen.
1873. *HENRICI, OLAUS M. F. E., Ph.D., F.R.S. (Pres. A, 1883; Council, 1883–89), Professor of Mechanics and Mathematics in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 34 Clarendon-road, Notting Hill, W.
1906. ‡Henry, Dr. T. A. Imperial Institute, S.W.
1909. *Henshall, Robert. Sunnyside, Latchford, Warrington.
1892. ‡HEPBURN, DAVID, M.D., F.R.S.E., Professor of Anatomy in University College, Cardiff.
1904. §Hepworth, Commander M. W. C., C.B., R.N.R. Meteorological Office, Victoria-street, S.W.
1892. *HERBERTSON, A. J., M.A., Ph.D., Reader in Geography in the University of Oxford. 43 Banbury-road, Oxford.
1909. §Herbertson, William. 313 Graham-avenue, Winnipeg, Canada.
1902. ‡Herdman, G. W., B.Sc., Assoc.M.Inst.C.E. Irrigation and Water Supply Department, Pretoria.
1887. *HERDMAN, WILLIAM A., D.Sc., F.R.S., F.R.S.E., F.L.S. (GENERAL SECRETARY, 1903– ; Pres. D, 1895; Council, 1894–1900; Local Sec. 1896), Professor of Natural History in the University of Liverpool. Croxteth Lodge, Sefton Park, Liverpool.
1893. *Herdman, Mrs. Croxteth Lodge, Sefton Park, Liverpool.
1909. §Herdt, Professor L. A. McGill University, Montreal, Canada.
1875. ‡HEREFORD, The Right Rev. JOHN PERCIVAL, D.D., LL.D., Lord Bishop of. (Pres. L, 1904.) The Palace, Hereford.
1908. *Herring, Dr. Percy T. The University, St. Andrews, N.B.
1874. §HERSCHEL, Colonel JOHN, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.
1900. *Herschel, Rev. J. C. W. Wooburn Green, Bucks.
1905. ‡Hervey, Miss Mary F. S. 22 Morpeth-mansions, S.W.
1903. *HESKETH, CHARLES H. FLEETWOOD, M.A. The Rookery, North Meols, Southport.
1895. §Hesketh, James. 5 Scarisbrick Avenue, Southport.
1905. ‡Hewat, M. L., M.D. Mowbray, near Cape Town, South Africa.
1894. ‡HEWETSON, G. H. (Local Sec. 1896.) 39 Henley-road, Ipswich.
1894. ‡Hewins, W. A. S., M.A., F.S.S. 15 Chartfield-avenue, Putney Hill, S.W.
1908. §Hewitt, Dr. C. Gordon. Central Experimental Farm, Ottawa.
1896. §Hewitt, David Basil, M.D. Oakleigh, Northwich, Cheshire.
1903. ‡Hewitt, E. G. W. 87 Princess-road, Moss Side, Manchester.
1909. §Hewitt, F. W., M.V.O., M.D. 14 Queen Anne-street, W.
1903. ‡Hewitt, John Theodore, M.A., D.Sc., Ph.D. 7 The Avenue, Surbiton, Surrey.

Year of Election.

1909. §Hewitt, W., B.Sc. 16 Clarence-road, Birkenhead.
1882. *HEYCOCK, CHARLES T., M.A., F.R.S. 3 St. Peter's-terrace, Cambridge.
1883. ‡Heyes, Rev. John Frederick, M.A., F.R.G.S. St. Barnabas Vicarage, Bolton.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1901. *Heys, Z. John. Stonehouse, Barrhead, N.B.
1886. ‡HEYWOOD, HENRY, J.P. Witla Court, near Cardiff.
1898. ‡Hicks, Henry B. 44 Pembroke-road, Clifton, Bristol.
1877. §HICKS, W. M., M.A., D.Sc., F.R.S. (Vice-Pres. 1910; Pres. A, 1895). Professor of Physics in the University of Sheffield. Leamhurst, Ivy Park-road, Sheffield.
1886. ‡Hicks, Mrs. W. M. Leamhurst, Ivy Park-road, Sheffield.
1887. *HICKSON, SYDNEY J., M.A., D.Sc., F.R.S. (Pres. D, 1903), Professor of Zoology in Victoria University, Manchester.
1864. *HIERN, W. P., M.A., F.R.S. The Castle, Barnstaple.
1891. ‡HIGGS, HENRY, C.B., LL.B., F.S.S. (Pres. F, 1899; Council, 1904–06.) H.M. Treasury, Whitehall, S.W.
1909. §Higman, Ormond. Electrical Standards Laboratory, Ottawa.
1907. ‡HILEY, E. V. (Local Sec. 1907.) Town Hall, Birmingham.
1885. *HILL, ALEXANDER, M.A., M.D. Downing College, Cambridge.
1903. *HILL, ARTHUR W., M.A., F.L.S. Royal Gardens, Kew.
1906. §Hill, Charles A., M.A., M.B. 13 Rodney-street, Liverpool.
1881. *HILL, Rev. EDWIN, M.A. The Rectory, Cockfield, Bury St. Edmunds.
1908. §Hill, James P., D.Sc., Professor of Zoology in University College, Gower-street, W.C.
1886. ‡HILL, M. J. M., M.A., D.Sc., F.R.S., Professor of Pure Mathematics in University College, W.C.
1898. *Hill, Thomas Sidney. 80 Harvard-court, West End-lane, N.W.
1885. *HILLHOUSE, WILLIAM, M.A., F.L.S., Professor of Botany in the University of Birmingham. 43 Calthorpe-road, Edgbaston, Birmingham.
1907. *HILLS, Major E. H., C.M.G., R.E., F.R.G.S. (Pres. E, 1908.) 32 Prince's-gardens, S.W.
1903. *Hilton, Harold. 73 Platt's-lane, Hampstead, N.W.
1903. *HIND, WHEELTON, M.D., F.G.S. Roxeth House, Stoke-on-Trent.
1870. ‡HINDE, G. J., Ph.D., F.R.S., F.G.S. Ivythorn, Avondale-road, South Croydon, Surrey.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1898. §Hinds, Henry. 57 Queen-street, Ramsgate.
1900. §Hinks, Arthur R., M.A. The Observatory, Cambridge.
1903. *Hinmers, Edward. Glentwood, South Downs-drive, Hale, Cheshire.
1899. ‡Hobday, Henry. Hazelwood, Crabble Hill, Dover.
1887. *Hobson, Bernard, M.Sc., F.G.S. Tapton Elms, Sheffield.
1883. ‡Hobson, Mrs. Carey. 5 Beaumont-crescent, West Kensington, W.
1904. §Hobson, Ernest William, Sc.D., F.R.S. The Gables, Mount Pleasant, Cambridge.
1907. ‡Hobson, Mrs. Mary. 6 Hopefield-avenue, Belfast.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1887. *Hodgkinson, Alexander, M.B., B.Sc., Lecturer on Laryngology in the Victoria University, Manchester. 18 St. John-street, Manchester.
1880. ‡Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., F.G.S., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 18 Glenluce-road, Blackheath, S.E.

Year of Election.

1905. ‡Hodgson, Ven. Archdeacon R. The Rectory, Wolverhampton.
1909. §Hodgson, R. T., M.A. Collegiate Institute, Brandon, Manitoba, Canada.
1898. ‡Hodgson, T. V. Municipal Museum and Art Gallery, Plymouth.
1904. §Hodson, F. Bedale's School, Petersfield, Hampshire.
1904. ‡HOGARTH, D. G., M.A. (Pres. H, 1907; Council, 1907– .) Chapel Meadow, Forest Row, Sussex.
1894. ‡*Hogg, A. F., M.A. 13 Victoria-road, Darlington.*
1908. ‡Hogg, Right Hon. Jonathan. Stratford, Rathgar, Co. Dublin.
1907. ‡Holden, Colonel H. C. L., R.A., F.R.S. Gifford House, Blackheath, S.E.
1883. ‡Holden, John J. 73 Albert-road, Southport.
1887. *Holder, Henry William, M.A. Beechmount, Arnside.
1900. ‡HOLDICH, Colonel Sir THOMAS H., R.E., K.C.B., K.C.I.E., F.R.G.S. (Pres. E, 1902.) 41 Courtfield-road, S.W.
1887. *Holdsworth, C. J. Fernhill, Alderley Edge, Cheshire.
1904. §Holland, Charles E. 9 Downing-place, Cambridge.
1903. §Holland, J. L., B.A. 3 Primrose-hill, Northampton.
1896. ‡Holland, Mrs. Lowfields House, Hooton, Cheshire.
1898. ‡Holland, Sir Thomas H., K.C.I.E., F.R.S., F.G.S. The University, Manchester.
1889. ‡Holländer, Bernard, M.D. 35A Welbeck-street, W.
1906. *Hollingworth, Miss. Leithen, Newnham-road, Bedford.
1905. ‡Hollway, H. C. Schunke. Plaisir de Merle, P.O. Simondium, *viâ* Paarl, South Africa.
1883. *Holmes, Mrs. Basil. 23 Corfton-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. 36 Buckingham-mansions, West End-lane, N.W.
1882. *HOLMES, THOMAS VINCENT, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1903. *HOLT, ALFRED, jun. Crofton, Aigburth, Liverpool.
1875. *Hood, John. Chesterton, Cirencester.
1904. §Hooke, Rev. D. Burford. Bonchurch Lodge, Barnet.
1847. ‡HOOKER, Sir JOSEPH DALTON, G.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. (PRESIDENT, 1868; Pres. E, 1881; Council, 1866–67.) The Camp, Sunningdale, Berkshire.
1892. ‡HOOKER, REGINALD H., M.A. 3 Clement's Inn, W.C.
1908. *Hooper, Frank Henry. Clare College, Cambridge.
1865. *Hooper, John P. Deepdene, Streatham Common, S.W.
1877. *Hooper, Rev. Samuel F., M.A. Lydlinch Rectory, Sturminster Newton, Dorset.
1904. ‡Hopewell-Smith, A., M.R.C.S. 37 Park-street, Grosvenor-square, S.W.
1905. *Hopkins, Charles Hadley. Junior Constitutional Club, 101 Piccadilly, W.
1901. *Hopkinson, Bertram, M.A., F.R.S.E., Professor of Mechanism and Applied Mechanics in the University of Cambridge. Adams-road, Cambridge.
1884. *HOPKINSON, CHARLES. (Local Sec. 1887.) The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Ferns, Alderley Edge, Cheshire.
1871. *HOPKINSON, JOHN, Assoc.Inst.C.E., F.L.S., F.G.S., F.R.Met.Soc. 84 New Bond-street, W.; and Weetwood, Watford.
1905. ‡Hopkinson, Mrs. John. Holmwood, Wimbledon Common, S.W.
1898. *Hornby, R., M.A. Haileybury College, Hertford.
1885. ‡HORNE, JOHN, LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1901. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1903. ‡Horne, William, F.G.S. Leyburn, Yorkshire.

Year of Election.

1902. ‡Horner, John. Chelsea, Antrim-road, Belfast.
1905. *Horsburgh, E. M., M.A., B.Sc., Lecturer in Technical Mathematics in the University of Edinburgh.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1893. *Horsley, Sir Victor A. H., LL.D., B.Sc., F.R.S., F.R.C.S. (Council, 1893–98.) 25 Cavendish-square, W.
1908. §Horton, F. St. John's College, Cambridge.
1884. *Hotblack, G. S. Brundall, Norwich.
1899. ‡Hotblack, J. T., F.G.S. 45 Newmarket-road, Norwich.
1906. *Hough, Miss Ethel M. Codsall Wood, near Wolverhampton.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1896. *Hough, S. S., M.A., F.R.S., F.R.A.S., His Majesty's Astronomer at the Cape of Good Hope. Royal Observatory, Cape Town.
1905. §Houghting, A. G. L. Glenelg, Musgrave-road, Durban, Natal.
1905. ‡Houseman, C. L. P.O. Box 149, Johannesburg.
1908. ‡Houston, David, F.L.S. Royal College of Science, Dublin.
1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, S.E.
1904. *Howard, Mrs. G. L. C. Agricultural Research Institute, Pusa, Bengal, India.
1887. *Howard, S. S. 58 Albemarle-road, Beckenham, Kent.
1901. §Howarth, E., F.R.A.S. Public Museum, Weston Park, Sheffield.
1903. *Howarth, James H., F.G.S. Somerley, Rawson-avenue, Halifax.
1907. ‡Howarth, O. J. R., M.A. (Assistant Secretary.) 24 Lansdowne-crescent, W.
1905. ‡Howick, Dr. W. P.O. Box 503, Johannesburg.
1901. ‡Howie, Robert Y. 3 Greenlaw-avenue, Paisley.
1863. ‡Howorth, Sir H. H., K.C.I.E., D.C.L., F.R.S., F.S.A. 30 Collingham-place, Cromwell-road, S.W.
1887. §Hoyle, William E., M.A., D.Sc. (Pres. D, 1907.) National Museum of Wales, City Hall, Cardiff.
1903. ‡Hübner, Julius. Ash Villa, Cheadle Hulme, Cheshire.
1898. ‡Hudson, Mrs. Sunny Bank, Egerton, Huddersfield.
1867. *Hudson, William H. H., M.A. 34 Birdhurst-road, Croydon.
1858. *Huggins, Sir William, K.C.B., D.C.L., LL.D., F.R.S., F.R.A.S. (President, 1891; Council, 1868–74, 1876–84.) 90 Upper Tulse-hill, S.W.
1871. *Hughes, George Pringle, J.P., F.R.G.S. Middleton Hall, Wooler, Northumberland.
1868. §Hughes, T. M'K., M.A., F.R.S., F.G.S. (Council, 1879–86), Woodwardian Professor of Geology in the University of Cambridge. Ravensworth, Brooklands-avenue, Cambridge.
1867. ‡Hull, Edward, M.A., LL.D., F.R.S., F.G.S. (Pres. C, 1874.) 14 Stanley-gardens, Notting Hill, W.
1903. ‡Hulton, Campbell G. Palace Hotel, Southport.
1905. §Hume, D. G. W. P.O. Box 1132, Johannesburg.
1901. ‡Hume, John H. Toronto, Canada; and 63 Bridgegate, Irvine.
1904. *Humphreys, Alexander C., Sc.D., LL.D., President of the Stevens Institute of Technology, Hoboken, New Jersey, U.S.A.
1907. §Humphries, Albert E. Coxe's Lock Mills, Weybridge.
1877. *Hunt, Arthur Roope, M.A., F.G.S. Southwood, Torquay.
1891. *Hunt, Cecil Arthur, Southwood, Torquay.
1881. ‡Hunter, F. W. 16 Old Elvet, Durham.
1889. ‡Hunter, Mrs. F. W. 16 Old Elvet, Durham.
1909. §Hunter, W. J. H. 31 Lynedoch-street, Glasgow.
1901. *Hunter, William. Evirallan, Stirling.
1903. ‡Hurst, Charles C., F.L.S. Burbage, Hinckley.

Year of Election.

1861. *Hurst, William John. Drumaness, Ballynahinch, Co. Down, Ireland.
1894. *HUTCHINSON, A., M.A., Ph.D. (Local Sec. 1904.) Pembroke College, Cambridge.
1903. §Hutchinson, Rev. H. N. 17 St. John's Wood Park, Finchley-road, N.W.
Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, N.W.
1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.
1908. ‡Hutton, Lucius O. Wyckham, Dundrum, Co. Dublin.
1901. *Hutton, R. S., D.Sc. West-street, Sheffield.
1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.
1900. *Hyndman, H. H. Francis. 5 Warwick-road, Earl's Court, S.W.

1908. ‡Idle, George. 43 Dawson-street, Dublin.
1883. ‡Idris, T. H. W., M.P. 110 Pratt-street, Camden Town, N.W.
Ihne, William, Ph.D. Heidelberg.
1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.
1906. ‡Iliffe, J. W. Oak Tower, Upperthorpe, Sheffield.
1885. ‡im Thurn, Sir Everard F., C.B., K.C.M.G. Colombo, Ceylon.
1888. *Ince, Surgeon-Major John, M.D. Montague House, Swanley, Kent.
1907. §Ingham, Charles B. Moira House, Eastbourne.
1905. ‡Ingham, W. Engineer's Office, Sand River, Uitenhage.
1893. ‡Ingle, Herbert. Department of Agriculture, Pretoria.
1901. ‡INGLIS, JOHN, LL.D. 4 Prince's-terrace, Dowanhill, Glasgow.
1905. §Innes, R. T. A., F.R.A.S. Meteorological Observatory, Johannesburg.
1901. *Ionides, Stephen A. Georgetown, Colorado.
1882. §IRVING, Rev. A., B.A., D.Sc. Hockerill Vicarage, Bishop's Stortford, Herts.
1908. ‡Irwin, Alderman John. 33 Rutland-square, Dublin.

1876. *JACK, WILLIAM, LL.D., Professor of Mathematics in the University of Glasgow. 10 The University, Glasgow.
1909. §Jacks, Professor L. P. 28 Holywell, Oxford.
1883. *Jackson, Professor A. H., B.Sc. 349 Collins-street, Melbourne, Australia.
1903. ‡Jackson, C. S. Royal Military Academy, Woolwich, S.E.
1883. *Jackson, F. J. 35 Leyland-road, Southport.
1883. ‡Jackson, Mrs. F. J. 35 Leyland-road, Southport.
1874. *Jackson, Frederick Arthur. Belmont, Somenos, Vancouver Island, B.C., Canada.
1899. ‡Jackson, Geoffrey A. 31 Harrington-gardens, Kensington, S.W.
1897. §Jackson, James, F.R.Met.Soc. Seabank, Girvan, N.B.
1906. *Jackson, James Thomas, M.A. Engineering School, Trinity College, Dublin.
1898. *Jackson, Sir John. 51 Victoria-street, S.W.
1905. ‡Jacobsohn, Lewis B. Lloyd's-buildings, 58 Burg-street, Cape Town.
1905. ‡Jacobsohn, Sydney Samuel. Lloyd's-buildings, 58 Burg-street, Cape Town.
1887. §Jacobson, Nathaniel, J.P. Olive Mount, Cheetham Hill-road, Manchester.
1905. *Jaffé, Arthur, B.A. Strandtown, Belfast.

Year of Election.

1874. *Jaffé, John. Villa Jaffé, 38 Promenade des Anglais, Nice, France.
1905. ‡Jagger, J. W. St. George's-street, Cape Town.
1906. ‡Jalland, W. H. Museum-street, York.
1891. *James, Charles Henry, J.P. 64 Park-place, Cardiff.
1891. *James, Charles Russell. 5 Raymond-buildings, Gray's Inn, W.C.
1904. ‡James, Thomas Campbell. University College, Aberystwyth.
1905. ‡Jameson, Adam. Office of the Commissioner of Lands, Pretoria.
1896. *Jameson, H. Lyster, M.A., Ph.D. Transvaal Technical Institute, Johannesburg.
1881. ‡Jamieson, Professor Andrew, M.Inst.C.E., F.R.S.E. 16 Rosslyn-terrace, Kelvinside. Glasgow.
1859. *Jamieson, Thomas F., LL.D., F.G.S. Ellon, Aberdeenshire.
1889. *Japp, F. R., M.A., Ph.D., LL.D., F.R.S. (Pres. B, 1898), Professor of Chemistry in the University of Aberdeen.
1896. *Jarmay, Gustav. Hartford Lodge, Hartford, Cheshire.
1903. ‡Jarratt, J. Ernest (Local Sec. 1903). 10 Cambridge-road, Southport.
1904. *Jeans, J. H., M.A., F.R.S., Professor of Applied Mathematics in Princeton University, Princeton, New Jersey, U.S.A.
1897. ‡Jeffrey, E. C., B.A. The University, Toronto, Canada.
1908. *Jenkin, Arthur Pearse, F.R.Met.Soc. Trewirgie, Redruth.
1909. *Jenkins, Miss Emily Vaughan. Lyceum Club, 128 Piccadilly, W.
1903. ‡Jenkinson, J. W. The Museum, Oxford.
1904. ‡Jenkinson, W. W. 6 Moorgate-street, E.C.
1893. §Jennings, G. E. Glen Helen, Narborough-road, Leicester.
1905. ‡Jennings, Sydney. P.O. Box 149, Johannesburg.
1905. ‡Jerome, Charles. P.O. Box 83, Johannesburg.
1887. ‡Jervis-Smith, Rev. F. J., M.A., F.R.S. Trinity College, Oxford.
Jessop, William. Overton Hall, Ashover, Chesterfield.
1900. *Jevons, H. Stanley, M.A., B.Sc. Woodhill, Rhiwbeina, near Cardiff.
1907. *Jevons, Miss H. W. 19 Chesterford-gardens, Hampstead, N.W.
1905. §Jeyes, Miss Gertrude, B.A. Berrymead, 6 Lichfield-road, Kew Gardens.
1905. ‡Jobson, J. B. P.O. Box 3341, Johannesburg.
1909. *Johns, Cosmo, F.G.S., M.I.M.E. Burngrove, Pitsmoor-road, Sheffield.
1884. ‡Johnson, Alexander, M.A., LL.D. 5 Prince of Wales-terrace, Montreal, Canada.
1909. §Johnson, C. Kelsall, F.R.G.S. The Glen, Sidmouth, Devon.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1890. *Johnson, Thomas, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.
1902. *Johnson, Rev. W., B.A., B.Sc. Archbishop Holgate's Grammar School, York.
1898. *Johnson, W. Claude, M.Inst.C.E. Broadstone, Coleman's Hatch, Sussex.
1899. ‡Johnston, Colonel Sir Duncan A., K.C.M.G., C.B., R.E., Hon. Sec. R.G.S. (Pres. E, 1909.) Branksome, Saffrons-road, Eastbourne.
1883. ‡Johnston, Sir H. H., G.C.M.G., K.C.B., F.R.G.S. 27 Chester-terrace, Regent's Park, N.W.
1909. §Johnston, J. Weir. 10 Lower Fitzwilliam-street, Dublin.
1908. ‡Johnston, Swift Paine. 1 Hume-street, Dublin.
1884. *Johnston, W. H. County Offices, Preston, Lancashire.
1885. ‡Johnston-Lavis, H. J., M.D., F.G.S. Beaulieu, Alpes-Maritimes, France.

Year of
Election.

1909. §Jolly, W. A., M.B. Physiological Laboratory, The University, Edinburgh.
1888. ‡Joly, John, M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1908), Professor of Geology and Mineralogy in the University of Dublin. Geological Department, Trinity College, Dublin.
1887. ‡Jones, D. E., B.Sc. Inglewood, Four Oaks, Sutton Coldfield.
1904. §Jones, Miss E. E. Constance. Girton College, Cambridge.
1890. §Jones, Rev. Edward, F.G.S. Primrose Cottage, Embsay, Skipton.
1896. ‡Jones, E. Taylor, D.Sc. University College, Bangor.
1903. §Jones, Evan. Ty-Mawr, Aberdare.
1907. *Jones, Mrs. Evan. 12 Hyde Park-gate, S.W.
1887. ‡Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *Jones, Rev. G. Hartwell, M.A. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. Inchyra House, 21 Cambridge-road, Waterloo, Liverpool.
1903. *Jones, H. O., M.A. Clare College, Cambridge.
1905. ‡Jones, Miss Parnell. The Rectory, Llanddewi Skirrid, Abergavenny, Monmouthshire.
1901. ‡Jones, R. E., J.P. Oakley Grange, Shrewsbury.
1902. ‡Jones, R. M., M.A. Royal Academical Institution, Belfast.
1908. ‡Jones, R. Pugh, M.A. County School, Holyhead, Anglesey.
1860. ‡Jones, Thomas Rupert, F.R.S., F.G.S. (Pres. C, 1891.) Penbryn, Chesham Bois-lane, Chesham, Bucks.
1875. *Jose, J. E. Ethersall, Tarbock-road, Huyton, Lancashire.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, S.W.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, Hon. Mrs. St. John's Croft, Winchester.
1905. ‡Judd, Miss Hilda M., B.Sc. Berrymead, 6 Lichfield-road, Kew.
1870. ‡Judd, John Wesley, C.B., LL.D., F.R.S., F.G.S. (Pres. C, 1885; Council, 1886–92.) Orford Lodge, 30 Cumberland-road, Kew.
1903. §Julian, Henry Forbes. Redholme, Braddon's Hill-road, Torquay.
1894. §Julian, Mrs. Forbes. Redholme, Braddon's Hill-road, Torquay.
1905. §Juritz, C. F., M.A., D.Sc., F.I.C. Government Analytical Laboratory, Parliament-street, Cape Town.

1888. ‡Kapp, Gisbert, M.Inst.C.E., M.Inst.E.E. Pen-y-Coed, Pritchatts-road, Birmingham.
1904. ‡Kayser, Professor H. The University, Bonn, Germany.
1892. ‡Keane, Charles A., Ph.D. Sir John Cass Technical Institute, Jewry-street, Aldgate, E.C.
1908. §Keeble, Frederick, Sc.D. University College, Reading.
1878. *Kelland, W. H. 27 Canterbury-road, Brixton, S.W.
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1908. §Kelly, Malachy. Ard Brugh, Dalkey, Co. Dublin.
1908. ‡Kelly, Captain Vincent Joseph. Montrose, Donnybrook, Co. Dublin.
1902. *Kelly, William J., J.P. 25 Oxford-street, Belfast.
1885. §Keltie, J. Scott, LL.D., Sec. R.G.S., F.S.S. (Pres. E, 1897; Council, 1898–1904.) 1 Savile-row, W.
1877. *Kelvin, Lady. Netherhall, Largs, Ayrshire; and 15 Eaton-place, S.W.
1887. ‡Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.

Year of
Election.

1898. *Kemp, John T., M.A. 4 Cotham-grove, Bristol.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.
1891. ‡KENDALL, PERCY F., M.Sc., F.G.S., Professor of Geology in the University of Leeds.
1875. ‡KENNEDY, Sir ALEXANDER B. W., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1894.) 1 Queen Anne-street, Cavendish-square, W.
1906. ‡Kennedy, Alfred Joseph, F.R.G.S. Care of Williams Deacon's Bank, Ltd., 2 Cockspur-street, S.W.
1897. §Kennedy, George, M.A., LL.D., K.C. Crown Lands Department, Toronto, Canada.
1906. ‡Kennedy, Robert Sinclair. Glengall Ironworks, Millwall, E.
1908. ‡Kennedy, William. 40 Trinity College, Dublin.
1905. *Kennerley, W. R. P.O. Box 158, Pretoria.
1893. §KENT, A. F. STANLEY, M.A., F.L.S., F.G.S., Professor of Physiology in University College, Bristol.
1901. ‡Kent, G. 16 Premier-road, Nottingham.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1909. §Kerr, Hugh L. 68 Admiral-road, Toronto, Canada.
1892. ‡KERR, J. GRAHAM, M.A., Professor of Natural History in the University, Glasgow.
1889. ‡Kerry, W. H. R. The Sycamores, Windermere.
1869. *Kesselmeyer, Charles Augustus. Roseville, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Edelweiss Villa, Albert-road, Hale, Cheshire.
1903. ‡Kewley, James. Balek Papan, Koltei, Dutch Borneo.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1905. ‡Kidd, Professor A. Stanley. Rhodes University College, Grahamstown, Cape Colony.
1902. ‡Kidd, George. Greenhaven, Malone Park, Belfast.
1906. ‡Kidner, Henry, F.G.S. 78 Gladstone-road, Watford.
1886. §KIDSTON, ROBERT, LL.D., F.R.S., F.R.S.E., F.G.S. 12 Clarendon-place, Stirling.
1901. *Kiep, J. N. 4 Hughenden-terrace, Kelvinside, Glasgow.
1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.
1896. *Killey, George Deane, J.P. Bentuther, 11 Victoria-road, Waterloo, Liverpool.
1890. ‡KIMMINS, C. W., M.A., D.Sc. Dame Armstrong House, Harrow.
1875. *KINCH, EDWARD, F.I.C., Professor of Chemistry in the Royal Agricultural College, Cirencester.
1872. **King, Mrs. E. M. Melrose, Alachua, Co. Florida, U.S.A.*
1888. *King, E. Powell. Wainsford, Lymington, Hants.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1883. *King, John Godwin. Stonelands, East Grinstead.
1883. *King, Joseph. Sandhouse, Witley, Godalming.
1908. §King, Professor L. A. L., M.A. St. Mungo's College Medical School, Glasgow.
1860. *King, Mervyn Kersteman. Merchants' Hall, Bristol.
1875. *King, Percy L. 2 Worcester-avenue, Clifton, Bristol.
1870. ‡King, William, M.Inst.C.E. 5 Beach-lawn, Waterloo, Liverpool.
1909. §Kingdon, A. 197 Yale-avenue, Winnipeg, Canada.
1903. §Kingsford, H. S., M.A. Royal Anthropological Institute, 50 Great Russell-street, W.C.
1900. ‡KIPPING, Professor F. STANLEY, D.Sc., Ph.D., F.R.S. (Pres. B, 1908.) University College, Nottingham.
1899. *Kirby, Miss C. F. 8 Windsor-court, Moscow-road, W.

Year of Election.

1907. §Kirby, William Forsell, F.L.S. Hilden, 46 Sutton Court-road, Chiswick, W.
1905. ‡Kirkby, Reginald G. P.O. Box 7, Pietermaritzburg, Natal.
1901. §Kitto, Edward. The Observatory, Falmouth.
1886. ‡Knight, Captain J. M., F.G.S. Bushwood, Wanstead, Essex.
1905. §Knightley, Lady, of Fawsley. Fawsley Park, Daventry.
1888. ‡KNOTT, Professor CARGILL G., D.Sc., F.R.S.E. 42 Upper Gray-street, Edinburgh.
1887. *Knott, Herbert, J.P. Sunnybank, Wilmslow, Cheshire.
1887. *Knott, John F. St. Martin's, Hooton, near Chester.
1906. *Knowles, Arthur J., B.A., M.Inst.C.E. Turf Club, Cairo, Egypt.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1903. ‡Knowlson, J. F. 26 Part-street, Southport.
1902. ‡KNOX, R. KYLE, LL.D. 1 College-gardens, Belfast.
1875. *Knubley, Rev. E. P., M.A. Steeple Ashton Vicarage, Trowbridge.
1883. ‡Knubley, Mrs. Steeple Ashton Vicarage, Trowbridge.
1905. ‡Koenig, J. P.O. Box 272, Cape Town.
1890. *Krauss, John Samuel, B.A. Stonycroft, Knutsford-road, Wilmslow, Cheshire.
1888 *Kunz, G. F., M.A., Ph.D. Care of Messrs. Tiffany & Co., 11 Union-square, New York City, U.S.A.

1905. ‡Lacey, William. Champ d'Or Gold Mining Co., Luipaardsvlei, Transvaal.
1903. *Lafontaine, Rev. H. C. de. 49 Albert-court, Kensington Gore, S.W.
1885. *Laing, J. Gerard. 3 Paper-buildings, Temple, E.C.
1909. §Laird, Hon. David. Indian Commission, Ottawa, Canada.
1904. ‡Lake, Philip. St. John's College, Cambridge.
1904. ‡Lamb, C. G. Ely Villa, Glisson-road, Cambridge.
1889. *Lamb, Edmund, M.A., M.P. Borden Wood, Liphook, Hants.
1887. ‡LAMB, HORACE, M.A., LL.D., D.Sc., F.R.S. (Pres. A, 1904), Professor of Pure Mathematics in the Victoria University, Manchester. 6 Wilbraham-road, Fallowfield, Manchester.
1909. §Lamb, J. R. 389 Graham-avenue, Winnipeg, Canada.
1903. ‡Lambert, Joseph. 9 Westmoreland-road, Southport.
1893. *LAMPLUGH, G. W., F.R.S., F.G.S. (Pres. C, 1906.) 13 Beaconsfield-road, St. Albans.
1905. ‡Lane, Rev. C. A. P.O. Box 326, Johannesburg.
1898. *LANG, WILLIAM H. 2 Heaton-road, Withington, Manchester.
1905. §Lange, John H. Judges' Chambers, Kimberley.
1886. *LANGLEY, J. N., M.A., D.Sc., F.R.S. (Pres. I, 1899; Council, 1904–07), Professor of Physiology in the University of Cambridge. Trinity College, Cambridge.
1865. ‡LANKESTER, Sir E. RAY, K.C.B., M.A., LL.D., D.Sc., F.R.S. (PRESIDENT, 1906; Pres. D, 1883; Council, 1889–90, 1894–95, 1900–02.) 29 Thurloe-place, S.W.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Morden College, Blackheath, London, S.E.
1884. ‡Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1885. ‡LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S. (Pres. C, 1892), Professor of Geology and Physiography in the University of Birmingham. 48 Frederick-road, Edgbaston, Birmingham
1909. §Larard, C. E., A.M.Inst.C.E. 106 Cranley-gardens, Muswell Hill, N.
1887 ‡Larmor, Alexander. Craglands, Helen's Bay, Co. Down.

Year of Election.

1881. ‡LARMOR, Sir JOSEPH, M.A., D.Sc., Sec.R.S. (Pres. A, 1900), Lucasian Professor of Mathematics in the University of Cambridge. St. John's College, Cambridge.
1883. §Lascelles, B. P., M.A. Headland, Mount Park, Harrow.
1896. *Last, William I. Victoria and Albert Museum, London, S.W.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. Parliament-mansions, Westminster, S.W.
1900. ‡Lauder, Alexander, Lecturer in Agricultural Chemistry in the Edinburgh and East of Scotland College of Agriculture, Edinburgh.
1892. ‡LAURIE, MALCOLM, B.A., D.Sc., F.L.S. School of Medicine, Surgeons' Hall, Edinburgh.
1883. ‡Laurie, Lieut.-General. 47 Porchester-terrace, W.
1907. *Laurie, Robert Douglas. Department of Zoology, The University, Liverpool.
1870. *Law, Channell. Ilsham Dene, Torquay.
1905. ‡Lawrence, Miss M. Roedean School, near Brighton.
1908. §Lawson, H. S., B.A. Westfield, Bath.
1908. ‡Lawson, William, LL.D. 27 Upper Fitzwilliam-street, Dublin.
1888. §Layard, Miss Nina F., F.L.S. Rookwood, Fonnereau-road, Ipswich.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1894. *LEAHY, A. H., M.A., Professor of Mathematics in the University of Sheffield. 92 Ashdell-road, Sheffield.
1905. ‡Leake, E. O. 5 Harrison-street, Johannesburg.
1901. *Lean, George, B.Sc. 15 Park-terrace, Glasgow.
1904. *Leathem, J. G. St. John's College, Cambridge.
1884. *Leavitt, Erasmus Darwin. 2 Central-square, Cambridgeport, Massachusetts, U.S.A.
1872. ‡LEBOUR, G. A., M.A., F.G.S., Professor of Geology in the Durham College of Science, Newcastle-on-Tyne.
1895. *Ledger, Rev. Edmund. Protea, Doods-road, Reigate.
1907. §Lee, Mrs. Barton. The Limes, Derby-road, Heaton Moor, Stockport.
1896. §Lee, Rev. H. J. Barton. The Limes, Derby-road, Heaton Moor, Stockport.
1909. §Lee, I. L. Care of Messrs. B. F. Stevens & Brown, 4 Trafalgar-square, W.C.
1909. §Lee, Rev. J. W., D.D. 33 Columbia-avenue, Atlanta, Georgia, U.S.A.
1894. *Lee, Mrs. W. Ashdown House, Forest Row, Sussex.
1884. *Leech, Sir Bosdin T. Oak Mount, Timperley, Cheshire.
1909. §Leeming, J. H., M.D. 406 Devon-court, Winnipeg, Canada.
1905. §Lees, Mrs. A. P. Care of Dr. Norris Wolfenden, 76 Wimpole-street, W.
1892. *LEES, CHARLES H., D.Sc., F.R.S., Professor of Physics in the East London College, Mile End. Greenacres, Mayfield-avenue, Woodford Green, Essex.
1886. *Lees, Lawrence W. Old Ivy House, Tettenhall, Wolverhampton.
1906. ‡Lees, Robert. Victoria-street, Fraserburgh.
1905. ‡Lees, R. Wilfrid. Pigg's Peak Development Co., Swaziland, South Africa.
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1906. ‡Leetham, Sidney. Elm Bank, York.
1905. ‡Legg, W. A. P.O. Box 1621, Cape Town.
1892. ‡LEHFELDT, ROBERT A. 56 *Norfolk-square, W.*

Year of Election.

1910. §Leigh, H. S. Brentwood, Worsley, near Manchester.
1891. ‡Leigh, W. W. Glyn Bargoed, Treharris, R.S.O., Glamorganshire.
1903. ‡Leighton, G. R., M.D., F.R.S.E., Professor of Pathology in the Royal Veterinary College, Edinburgh.
1906. ‡Leiper, Robert T., M.B., F.Z.S. London School of Tropical Medicine, Royal Albert Dock, E.
1905. ‡Leitch, Donald. P.O. Box 1703, Johannesburg.
1882. §Lemon, Sir James, M.Inst.C.E., F.G.S. 11 The Avenue, Southampton.
1903. *Lempfert, R. G. K., M.A. Meteorological Office, 63 Victoria-street, S.W.
1908. ‡Lentaigne, John. 42 Merrion-square, Dublin.
1887. *Leon, John T. Elmwood, Grove-road, Southsea.
1901. §LEONARD, J. H., B.Sc. 28 Talgarth-road, West Kensington, W.
1905. ‡Leonard, Right Rev. Bishop John. St. Mary's, Cape Town.
1904. ‡*Lepper, Alfred William. 6 Trinity College, Dublin.*
1890. *Lester, Joseph Henry, Royal Exchange, Manchester.
1904. *Le Sueur, H. R., D.Sc. Chemical Laboratory, St. Thomas's Hospital, S.E.
1900. ‡Letts, Professor E. A., D.Sc., F.R.S.E. Queen's College, Belfast.
1896. ‡Lever, W. H. Thornton Manor, Thornton Hough, Cheshire.
1905. ‡Levin, Benjamin. P.O. Box 74, Cape Town.
1887. *Levinstein, Ivan. Hawkesmoor, Fallowfield, Manchester.
1893. *LEWES, VIVIAN B., F.C.S., Professor of Chemistry in the Royal Naval College, Greenwich, S.E.
1905. ‡Lewin, J. B. Duncan's-chambers, Shortmarket-street, Cape Town.
1904. *Lewis, Mrs. Agnes S., LL.D. Castle Brae, Chesterton-lane, Cambridge.
1870. ‡LEWIS, ALFRED LIONEL. 35 Beddington-gardens, Wallington, Surrey.
1891. ‡Lewis, Professor D. Morgan, M.A. University College, Aberystwyth.
1905. ‡Lewis, F. S., M.A. South African Public Library, Cape Town.
1904. ‡Lewis, Hugh. Glanafrau, Newtown, Montgomeryshire.
1909. §Lewis, J. W. 67 Cadogan-place, W.
1884. *Lewis, Sir W. T., Bart. The Mardy, Aberdare.
1903. §Lewkowitsch, Dr. J. 71 Priory-road, N.W.
1906. §Liddiard, James Edward, F.R.G.S. Rodborough Grange, Bournemouth.
1908. ‡Lilly, W. E., M.A., Sc.D. 39 Trinity College, Dublin.
1904. ‡Link, Charles W. 14 Chichester-road, Croydon.
1898. §Lippincott, R. C. Cann. Over Court, near Bristol.
1895. *LISTER, The Right Hon. Lord, F.R.C.S., D.C.L., D.Sc., F.R.S. (PRESIDENT, 1896.) 12 Park-crescent, Portland-place, W.
1888. ‡LISTER, J. J., M.A., F.R.S. (Pres. D, 1906.) St. John's College, Cambridge.
1861. *LIVEING, G. D., M.A., F.R.S. (Pres. B, 1882; Council 1888–95; Local Sec. 1862.) Newnham, Cambridge.
1876. *LIVERSIDGE, ARCHIBALD, M.A., F.R.S., F.C.S., F.G.S., F.R.G.S. Hornton Cottage, Hornton-street, Kensington, W.
1902. §Llewellyn, Evan. Working Men's Institute and Hall, Blaenavon.
1909. §Lloyd, George C., Secretary of the Iron and Steel Institute. 28 Victoria-street, S.W.
1903. §Lloyd, Godfrey I. H. The University of Toronto, Canada.
1891. *LLOYD, *R. J., M.A., D.Litt., F.R.S.E.* 49A *Grove-street, Liverpool.*
1854. *LOBLEY, J. LOGAN, F.G.S., F.R.G.S. 36 Palace-street, Buckingham Gate, S.W.

Year of Election.

1892. ‡LOCH, C. S., D.C.L. Denison House, Vauxhall Bridge-road, S.W.
1905. ‡Lochrane, Miss T. 8 Prince's-gardens, Dowanhill, Glasgow.
1904. ‡Lock, Rev. J. B. Herschel House, Cambridge.
1863. ‡LOCKYER, Sir J. NORMAN, K.C.B., LL.D., D.Sc., F.R.S. (PRESIDENT, 1903; Council, 1871-76, 1901-02.) 16 Penywern-road, S.W.
1902. *Lockyer, Lady. 16 Penywern-road, S.W.
1900. §LOCKYER, W. J. S., Ph.D. 16 Penywern-road, S.W.
1886. *LODGE, ALFRED, M.A. The Croft, Peperharow-road, Godalming.
1875. *LODGE, Sir OLIVER J., D.Sc., LL.D., F.R.S. (Pres. A, 1891; Council, 1891-97, 1899-1903), Principal of the University of Birmingham.
1894. *Lodge, Oliver W. F. 17 Ruskin-buildings, Westminster, S.W.
1899. §Loncq, Emile. 6 Rue de la Plaine, Laon, Aisne, France.
1902. ‡LONDONDERRY, The Marquess of, K.G. Londonderry House, Park-lane, W.
1903. ‡Long, Frederick. The Close, Norwich.
1905. ‡Long, W. F. City Engineer's Office, Cape Town.
1883. *Long, William. Thelwall Heys, near Warrington.
1904. *Longden, J. A., M.Inst.C.E. Stanton-by-Dale, Nottingham.
1905. §Longden, Mrs. J. B. Stanton-by-Dale, Nottingham.
1898. *Longfield, Miss Gertrude. Belmont, High Halstow, Rochester.
1901. *Longstaff, Frederick V., F.R.G.S. Ridgelands, Wimbledon, Surrey.
1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, S.W.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, S.W.
1899. *Longstaff, Tom G., M.A., M.D. Ridgelands, Wimbledon, S.W.
1903. ‡Loton, John, M.A. 23 Hawkshead-street, Southport.
1897. ‡LOUDON, JAMES, LL.D., President of the University of Toronto, Canada.
1883. *LOUIS, D. A., F.I.C. Savage Club, W.C.
1896. §Louis, Henry, M.A., Professor of Mining in the Durham College of Science, Newcastle-on-Tyne.
1887. *LOVE, A. E. H., M.A., D.Sc., F.R.S. (Pres. A, 1907), Professor of Natural Philosophy in the University of Oxford. 34 St. Margaret's-road, Oxford.
1886. *Love, E. F. J., D.Sc., M.A. The University, Melbourne, Australia.
1904. *Love, J. B. Outlands, Devonport.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 33 Clanricarde-gardens, W.
1905. ‡Loveday, Professor T. South African College, Cape Town.
1908. §Low, Alexander, M.A., M.B. Marischal College, Aberdeen.
1909. §Low, David, M.D. 1927 Scarth-street, Regina, Saskatchewan, Canada.
1885. §Lowdell, Sydney Poole. Baldwin's Hill, East Grinstead, Sussex.
1891. §Lowdon, John. St. Hilda's, Barry, Glamorgan.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1905. ‡Lowe, E. C. Chamber of Trade, Johannesburg.
1886. *Lowe, John Landor, B.Sc., M.Inst.C.E. Spondon, Derbyshire.
1894. ‡Lowenthal, Miss Nellie. Woodside, Egerton, Huddersfield.
1903. *LOWRY, Dr. T. MARTIN. 130 Horseferry-road, S.W.
1901. *Lucas, Keith. Greenhall, Forest Row, Sussex.
1891. *Lucovich, Count A. Tyn-y-parc, Whitchurch, near Cardiff.
1906. §Ludlam, Ernest Bowman. College Gate, 32 College-road, Clifton, Bristol.
1866. *Lund, Charles. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 32 Newport-road, Cardiff.
1905. ‡Lunnon, F. J. P.O. Box 400, Pretoria.

Year of Election.

1883. *Lupton, Arnold, M.P., M.Inst.C.E., F.G.S. 7 Victoria-street, S.W.
1874. *Lupton, Sydney, M.A. (Local Sec. 1890.) 102 Park-street, Grosvenor-square, W.
1898. §Luxmoore, Dr. C. M. Central Technical Schools, Truro.
1903. ‡Lyddon, Ernest H. Lisvane, near Cardiff.
1884. ‡Lyman, H. H. 384 St. Paul-street, Montreal, Canada.
1907. *Lyons, Captain Henry George, R.E., D.Sc., F.R.S. 34 Huntly-gardens, Glasgow.
1908. §Lyster, George H. 34 Dawson-street, Dublin.
1908. ‡Lyster, Thomas W., M.A. National Library of Ireland, Kildare-street, Dublin.

1905. ‡Maberly, Dr. John. Shirley House, Woodstock, Cape Colony.
1868. ‡Macalister, Alexander, M.A., M.D., F.R.S. (Pres. H, 1892; Council. 1901–06), Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.
1878. ‡MacAlister, Sir Donald, K.C.B., M.A., M.D., LL.D., B.Sc., Principal of the University of Glasgow.
1904. ‡Macalister, Miss M. A. M. Torrisdale, Cambridge.
1908. ‡Macallan, J., F.I.C., F.R.S.E. 3 Rutland-terrace, Clontarf, Co. Dublin.
1896. ‡Macallum, Professor A. B., Ph.D., D.Sc., F.R.S. (Local Sec. 1897.) 59 St. George-street, Toronto, Canada.
1879. §MacAndrew, James J., F.L.S. Lukesland, Ivybridge, South Devon.
1883. ‡MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1909. §MacArthur, J. A., M.D. Canada Life Building, Winnipeg, Canada.
1896. *Macaulay, F. S., M.A. 19 Dewhurst-road, W.
1904. *Macaulay, W. H. King's College, Cambridge.
1896. ‡MacBride, Professor E. W., M.A., D.Sc., F.R.S. McGill University, Montreal, Canada.
1902. *Maccall, W. T., M.Sc. Municipal Technical College, Halifax, Yorkshire.
1886. ‡MacCarthy, Rev. E. F. M., M.A. 50 Harborne-road, Edgbaston, Birmingham.
1908. §McCarthy, Edward Valentine, J.P. Ardmanagh House, Glenbrook, Co. Cork.
1909. §McCarthy, J. H. Public Library, Winnipeg, Canada.
1884. *McCarthy, J. J., M.D. 83 Wellington-road, Dublin.
1887. *McCarthy, James. Care of Sir Sherston Baker, Bart., 18 Cavendish-road, Regent's Park, N.W.
1904. §McClean, Frank Kennedy. Rusthall House, Tunbridge Wells.
1876. *M'Clelland, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1902. ‡McClelland, J. A., M.A., Professor of Physics in University College, Dublin.
1906. ‡McClure, Rev. E. 80 Eccleston-square, S.W.
1878. *M'Comas, Henry. Pembroke House, Pembroke-road, Dublin.
1908. §McCombie, Hamilton, M.A., Ph.D. The University, Birmingham.
1901. *MacConkey, Alfred. Queensberry Lodge, Elstree, Herts.
1905. ‡McConnell, D. E. Montrose-avenue, Orangezicht, Cape Town.
1901. ‡MacCormac, J. M., M.D. 31 Victoria-place, Belfast.
1892. *McCowan, John, M.A., D.Sc. Henderson-street, Bridge of Allan, N.B.
1901. ‡McCrae, John, Ph.D. 7 Kirklee-gardens, Glasgow.
1905. §McCulloch, Principal J. D. Free College, Edinburgh.
1904. ‡McCulloch, Major T., R.A. 68 Victoria-street, S.W.
1909. §MacDonald, Miss Eleanor. Fort Qu'Appelle, Saskatchewan, Canada.

Year of Election.

1904. ‡Macdonald, H. M., M.A., F.R.S., Professor of Mathematics in the University of Aberdeen.
1905. ‡McDonald, J. G. P.O. Box 67, Bulawayo.
1900. ‡MacDonald, J. Ramsay, M.P. 3 Lincoln's Inn-fields, W.C.
1890. *MacDonald, Mrs. J. Ramsay. 3 Lincoln's Inn-fields, W.C.
1905. §Macdonald, J. S., B.A., Professor of Physiology in the University of Sheffield.
1884. *Macdonald, Sir W. C. 449 Sherbrooke-street West, Montreal, Canada.
1909. §MacDonell, John, M.D. Portage-avenue, Winnipeg, Canada.
1909. *MacDougall, R. Stewart. The University, Edinburgh.
1908. §McEwen, Walter, J.P. Flowerbank, Newton Stewart, Scotland.
1897. ‡McEwen, William C. 9 South Charlotte-street, Edinburgh.
1881. ‡Macfarlane, Alexander, D.Sc., F.R.S.E. 317 Victoria-avenue, Chatham, Ontario, Canada.
1906. §McFarlane, John. 30 Parsonage-road, Withington, Manchester.
1885. ‡Macfarlane, J. M., D.Sc., F.R.S.E., Professor of Biology in the University of Pennsylvania, Lansdowne, Delaware Co., Pennsylvania, U.S.A.
1905. ‡Macfarlane, T. J. M. P.O. Box 1198, Johannesburg.
1901. ‡Macfee, John. 5 Greenlaw-terrace, Paisley.
1909. §Macgachen, A. F. D. 281 River-avenue, Winnipeg, Canada.
1888. ‡MacGeorge, James. 8 Matheson-road, Kensington, W.
1908. ‡McGrath, Joseph, LL.D. (Local Sec. 1908.) Royal University of Ireland, Dublin.
1908. §MacGregor, Charles. Training Centre, Charlotte-street, Aberdeen.
1906. ‡Macgregor, D. H., M.A. Trinity College, Cambridge.
1884. *MacGregor, James Gordon, M.A., D.Sc., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh.
1902. ‡McIlroy, Archibald. Glenvale, Drumbo, Lisburn, Ireland.
1905. ‡Macindoe, Flowerdue. 23 Saratoga-avenue, Johannesburg.
1867. *McIntosh W. C., M.D., LL.D., F.R.S., F.R.S.E., F.L.S. (Pres. D, 1885), Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1909. §McIntyre, Alexander. 142 Maryland-avenue, Winnipeg, Canada.
1909. §McIntyre, Daniel. School Board Offices, Winnipeg, Canada.
1909. §McIntyre, W. A. 339 Kennedy-street, Winnipeg, Canada.
1884. §MacKay, A. H., B.Sc., LL.D., Superintendent of Education. Education Office, Halifax, Nova Scotia, Canada.
1885. ‡Mackay, John Yule, M.D., LL.D., Principal of and Professor of Anatomy in University College, Dundee.
1908. §McKay, William, J.P. Clifford-chambers, York.
1873. ‡McKendrick, John G., M.D., LL.D., F.R.S., F.R.S.E. (Pres. I, 1901; Council, 1903-09), Professor of Physiology in the University of Glasgow. Maxieburn, Stonehaven, N.B.
1909. §McKenty, D. E. 104 Colony-street, Winnipeg, Canada.
1905. ‡McKenzie, A. R. P.O. Box 214, Cape Town.
1907. §McKenzie, Alexander, M.A., D.Sc., Ph.D. Birkbeck College, Bream's-buildings, Chancery-lane, E.C.
1905. ‡Mackenzie, Hector. Standard Bank of South Africa, Cape Town.
1897. ‡McKenzie, John J. 61 Madison-avenue, Toronto, Canada.
1909. §MacKenzie, Kenneth. Royal Alexandra Hotel, Winnipeg, Canada.
1901. *Mackenzie, Thomas Brown. Netherby, Manse-road, Motherwell, N.B.
1872. *Mackey, J. A. United University Club, Pall Mall East, S.W.
1901. ‡Mackie, William, M.D. 13 North-street, Elgin.
1887. ‡Mackinder, H. J., M.A., F.R.G.S. (Pres. E, 1895; Council, 1904-1905.) 243 St. James's-court, Buckingham-gate, S.W.

Year of Election.

1908. §MacKinnon, Mrs. Donald. Speldhurst Rectory, Tunbridge Wells.
1885. *M'Laren, The Hon. Lord, F.R.S.E., F.R.A.S. 46 Moray-place, Edinburgh.
1894. *McLaren, Mrs. E. L. Colby, M.B., Ch.B. 228 Rotton Park-road, Edgbaston, Birmingham.
1901. ‡Maclaren, J. Malcolm. Royal Colonial Institute, Northumberland Avenue, W.C.
1905. ‡McLaren, Thomas. P.O. Box 1034, Johannesburg.
1901. ‡Maclay, William. Thornwood, Langside, Glasgow.
1901. ‡McLean, Angus, B.Sc. Ascog, Meikleriggs, Paisley.
1905. ‡*MacLean, Lachlan. Greenhill, Kenilworth, Cape Colony.*
1892. *Maclean, Magnus, M.A., D.Sc., F.R.S.E. (Local Sec. 1901), Professor of Electrical Engineering, Technical College, Glasgow.
1909. §MacLean, Neil Bruce. 24 Hitchcock Hall, The University, Chicago. U.S.A.
1908. §McLennan, J. C. The University, Toronto, Canada.
1868. §McLeod, Herbert, F.R.S. (Pres. B, 1892; Council, 1885–90.) 37 Montague-road, Richmond, Surrey.
1909. §MacLeod, M. H. C.N.R. Depôt, Winnipeg, Canada.
1883. ‡MacMahon, Major Percy A., R.A., D.Sc., F.R.S. (General Secretary, 1902– ; Pres. A, 1901; Council, 1898–1902.) 27 Evelyn-mansions, Carlisle-place, S.W.
1909. §McMillan, The Hon. Sir Daniel H., K.C.M.G. Government House, Winnipeg, Canada.
1902. ‡McMordie, Robert J. Cabin Hill, Knock, Co. Down.
1905. ‡MacNay, Arthur. Cape Government Railway Offices, De Aar, Cape Colony.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1905. §Macphail, Dr. S. Rutherford. Rowditch, Derby.
1909. §MacPhail, W. M. P.O. Box 88, Winnipeg, Canada.
1905. ‡Macrae, Harold J. P.O. Box 817, Johannesburg.
1907. §Macrosty, Henry W. 29 Hervey-road, Blackheath, S.E.
1906. ‡Macturk, G. W. B. 15 Bowlalley-lane, Hull.
1908. ‡McVittie, R. B., M.D. 62 Fitzwilliam-square North, Dublin.
1908. ‡McWalter, J. C., M.D., M.A. 19 North Earl-street, Dublin.
1902. ‡McWeeney, Professor E. J., M.D. 84 St. Stephen's-green, Dublin.
1902. ‡*McWhirter, William. 9 Walworth-terrace, Glasgow.*
1908. ‡Madden, Rt. Hon. Mr. Justice. Nutley, Booterstown, Dublin.
1905. §Magenis, Lady Louisa. 34 Lennox-gardens, S.W.
1902. ‡*Magill, R., M.A., Ph.D. The Manse, Maghera, Co. Derry.*
1909. §Magnus, Laurie, M.A. 12 Westbourne-terrace, W.
1875. *Magnus, Sir Philip, B.Sc., B.A., M.P. (Pres. L, 1907). 16 Gloucester-terrace, Hyde Park, W.
1908. *Magson, Egbert H. 67 Pepys-road, Cottenham Park, Wimbledon, S.W.
1902. ‡*Mahon, J. L. 2 May-street, Drumcondra, Dublin.*
1907. *Mair, David. Civil Service Commission, Burlington-gardens, W.
1908. ‡Mair, William, F.C.S. 7 Comiston-road, Edinburgh.
1908. *Makower, W. The University, Manchester.
1857. ‡Mallet, John William, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, Albemarle Co., U.S.A.
1905. ‡Maltby, Lieutenant G. R., R.N. 54 St. George's-square, S.W.
1897. ‡Mance, Sir H. C. Old Woodbury, Sandy, Bedfordshire.
1903. ‡Manifold, C. C. 16 St. James's-square, S.W.
1905. ‡Manning, D. W., F.R.G.S. Roydon, Rosebank, Cape Town.
1894. ‡Manning, Percy, M.A., F.S.A. Watford, Herts.
1905. ‡Mansfield, J. D. 94 St. George's-street, Cape Town.

Year of Election.

1887. *March, Henry Colley, M.D., F.S.A. Portesham, Dorchester. Dorsetshire.
1902. *MARCHANT, Dr. E. W. The University, Liverpool.
1898. *Mardon, Heber. 2 Litfield-place, Clifton, Bristol.
1900. ‡Margerison, Samuel. Calverley Lodge, near Leeds.
1864. ‡MARKHAM, Sir CLEMENTS R., K.C.B., F.R.S., F.R.G.S., F.S.A. (Pres. E. 1879; Council, 1893-96.) 21 Eccleston-square, S.W.
1905. §Marks, Samuel. P.O. Box 379, Pretoria.
1905. ‡Marloth, R., M.A., Ph.D. P.O. Box 359, Cape Town.
1881. *MARR, J. E., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1896; Council, 1896-1902.) St. John's College, Cambridge.
1903. §Marriott, William. Royal Meteorological Society, 70 Victoria-street, S.W.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.
1883. *Marsh, Henry Carpenter. 3 Lower James-street, Golden-square, W.
1887. ‡Marsh, J. E., M.A., F.R.S. University Museum, Oxford.
1889. *MARSHALL, ALFRED, M.A., LL.D., D.Sc. (Pres. F, 1890.) Balliol Croft, Madingley-road, Cambridge.
1904. ‡Marshall, F. H. A. University of Edinburgh.
1905. §Marshall, G. A. K. 6 Chester-place, Hyde Park-square, W.
1892. §MARSHALL, HUGH, D.Sc., F.R.S., F.R.S.E., Professor of Chemistry in University College, Dundee.
1901. ‡Marshall, Robert. 97 Wellington-street, Glasgow.
1885. *MARSHALL, WILLIAM BAYLEY, M.Inst.C.E. Imperial Hotel, Malvern.
1907. ‡Marston, Robert. 14 Ashleigh-road, Leicester.
1899. §Martin, Miss A. M. Park View, 32 Bayham-road, Sevenoaks.
1891. *Martin, Edward P., J.P. The Hill, Abergavenny, Monmouthshire.
1905. ‡Martin, John. P.O. Box 217, Germiston, Transvaal.
1884. §Martin, N. H., J.P., F.R.S.E., F.L.S. Ravenswood, Low Fell, Gateshead.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Hughenden, New Barnet, Herts.
1905. ‡Marwick, J. S. P.O. Box 1166, Johannesburg.
1905. ‡Marx, Mrs. Charles. Shabana, Robinson-street, Belgravia, South Africa.
1907. ‡Masefield, J. R. B., M.A. Rosehill, Cheadle, Staffordshire.
1847. ‡MASKELYNE, NEVIL STORY, M.A., D.Sc., F.R.S., F.G.S. (Council, 1874-80). Basset Down House, Swindon.
1905. *Mason, Justice A. W. Supreme Court, Pretoria.
1893. *Mason, Thomas. Enderleigh, Alexandra Park, Nottingham.
1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
1905. §Massy, Miss Mary. York House, Teignmouth, Devon.
1898. ‡*Masterman, A. T. University of St. Andrews, N.B.*
1901. *Mather, G. R. Boxlea, Wellingborough.
1887. *Mather, Sir William, M.Inst.C.E. Salford Iron Works, Manchester.
1909. §Mathers, Justice. 16 Edmonton-street, Winnipeg, Canada.
1908. ‡Matheson, Sir R. E., LL.D. Charlemont House, Rutland-square, Dublin.
1905. ‡Mathew, Alfred Harfield. P.O. Box 242, Cape Town.
1894. ‡MATHEWS, G. B., M.A., F.R.S. St. John's College, Cambridge.
1902. ‡Matley, C. A., D.Sc. 7 Morningside-terrace, Edinburgh.
1904. ‡Matthews, D. J. The Laboratory, Citadel Hill, Plymouth.
1905. ‡Matthews, J. Wright, M.D. P.O. Box 437, Johannesburg.
1899. *Maufe, Herbert B., B.A., F.G.S. Geological Survey Office, 33 George-square, Edinburgh.

Year of Election.

1893. ‡Mavor, Professor James. University of Toronto, Canada.
1865. *Maw, George, F.L.S., F.G.S., F.S.A. Benthall, Kenley, Surrey.
1894. §Maxim, Sir Hiram S. Thurlow Park, Norwood-road, West Norwood, S.E.
1903. ‡*Maxwell, J. M.* 37 *Ash-street, Southport.*
1901. *May, W. Page, M.D., D.Sc. 14 Great Cumberland-place, W.
1905. §Maylard, A. Ernest. 12 Blythswood-square, Glasgow.
1905. ‡Maylard, Mrs. 12 Blythswood-square, Glasgow.
1878. *Mayne, Thomas. 19 Lord Edward-street, Dublin.
1904. ‡Mayo, Rev. J., LL.D. 6 Warkworth-terrace, Cambridge.
1905. ‡Mearns, J. Herbert, M.D. Edenville, 10 Oxford-road, Observatory, Cape Town.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, W.
1905. §Mein, W. W. P.O. Box 1145, Johannesburg.
1881. *Meldola, Raphael, F.R.S., F.R.A.S., F.C.S., F.I.C. (Pres. B, 1895; Council, 1892-99), Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, W.C.
1908. ‡Meldrum, A. N., D.Sc. Chemical Department, The University, Manchester.
1883. ‡Mellis, Rev. James. 23 Part-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡Mello, Rev. J. M., M.A., F.G.S. Cliff Hill, Warwick.
1881. §Melrose, James. Clifton Croft, York.
1905. *Melvill, E. H. V., F.G.S., F.R.G.S. P.O. Box 719, Johannesburg.
1901. ‡*Mennell, F. P.* 8 *Addison-road, W.*
1909. §Menzies, Rev. James, M.D. Hwaichingfu, Honan, China.
1905. ‡Meredith, H. O. Hollycroft, Cavendish-avenue, Cambridge.
1908. ‡Meredith, Sir James Creed, LL.D. Royal University of Ireland, Dublin.
1879. ‡Merivale, John Herman, M.A. (Local Sec. 1889.) Togston Hall, Acklington.
1899. *Merrett, William H., F.I.C. Hatherley, Grosvenor-road, Wallington, Surrey.
1905. ‡Merriman, Right Hon. John X. Schoongezicht, Stellenbosch, Cape Colony.
1899. ‡Merryweather, J. C. 4 Whitehall-court, S.W.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1905. ‡Methven, Cathcart W. Club Arcade, Smith-street, Durban.
1896. §Metzler, W. H., Ph.D., Professor of Mathematics in Syracuse University, Syracuse, New York, U.S.A.
1869. ‡Miall, Louis C., D.Sc., F.R.S., F.L.S., F.G.S. (Pres. D, 1897; Pres. L, 1908; Local Sec. 1890.) Norton Way North, Letchworth.
1903. *Mickletwait, Miss Frances M. G. Penhein, Chepstow, Monmouth.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of. Bishop's House, Middlesbrough.
1904. ‡Middleton, T. H., M.A. South House, Barton-road, Cambridge
1894. *Miers, H. A., M.A., F.R.S., F.G.S. (Pres. C, 1905), Principal of the University of London. 23 Wetherby-gardens, S.W.
1885. §Mill, Hugh Robert, D.Sc., LL.D., F.R.S.E., F.R.G.S. (Pres. E, 1901.) 62 Camden-square, N.W.
1905. ‡Mill, Mrs. H. R. 62 Camden-square, N.W.
1889. *Millar, Robert Cockburn, 30 York-place, Edinburgh.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1909. §Miller, A. C. E. Vermilion Bay, Ontario, Canada.
1895. ‡Miller, Thomas, M.Inst.C.E. 9 Thoroughfare, Ipswich.

Year of
Election.

1909. §Miller, Professor W. G. Bureau of Mines, Toronto, Canada.
1902. ‡Millin, S. T. Sheridan Lodge, Helen's Bay, Co. Down.
1904. ‡Millis, C. T. Hollydene, Wimbledon Park-road, Wimbledon.
1905. §Mills, Mrs. A. A. Ceylon Villa, Blinco-grove, Cambridge.
1908. §Mills, Miss E. A. Nurney, Glenagarey, Co. Dublin.
1868. *Mills, Edmund J., D.Sc., F.R.S., F.C.S. 64 Twyford-avenue, West Acton, W.
1908. §Mills, Miss Gertrude Isabel. Nurney, Glenagarey, Co. Dublin.
1908. §Mills, John Arthur, M.B. Durham County Asylum, Winterton, Ferryhill.
1908. §Mills, W. H., M.Inst.C.E. Nurney, Glenagarey, Co. Dublin.
1902. ‡Mills, W. Sloan, M.A. Vine Cottage, Donaghmore, Newry.
1907. ‡Milne, A., M.A. University School, Hastings.
1882. *Milne, John, D.Sc., F.R.S., F.G.S. Shide, Newport, Isle of Wight.
1903. *Milne, R. M. Royal Naval College, Dartmouth, South Devon.
1898. *Milner, S. Roslington, D.Sc. The University, Sheffield.
1908. §Milroy, T. H., M.D., Dunville Professor of Physiology in Queen's College, Belfast.
1907. §Milton, J. H., F.G.S. Harrison House, Crosby, Liverpool.
1880. ‡Minchin, G. M., M.A., F.R.S., Professor of Mathematics in the Royal Indian Engineering College, Coopers Hill, Surrey.
1901. *Mitchell, Andrew Acworth. 7 Huntly-gardens, Glasgow.
1901. *Mitchell, G. A. 5 West Regent-street, Glasgow.
1909. §Mitchell, J. F. 211 Rupert-street, Winnipeg, Canada.
1905. ‡Mitchell, John. Government School House, Jeppestown, Transvaal.
1885. ‡Mitchell, P. Chalmers, M.A., D.Sc., F.R.S., Sec.Z.S. (Council, 1906–). 3 Hanover-square, W.
1905. *Mitchell, William Edward. Ferreira Deep, Johannesburg.
1908. ‡Mitchell, W. M. 2 St. Stephen's Green, Dublin.
1905. ‡Mitter, M. Care of J. Speak, Esq., The Grange, Kirton, near Boston.
1895. *Moat, William, M.A. Johnson Hall, Eccleshall, Staffordshire.
1908. ‡Moffat, C. B. 36 Hardwicke-street, Dublin.
1905. §Moir, James, D.Sc. Mines Department, Johannesburg.
1905. ‡Moir, Dr. W. Ironside. Care of Dr. McAulay, Cleveland, Transvaal.
1905. §Molengraaff, Professor G. A. F. The Technical University of Delft, The Hague.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1908. ‡Molloy, W. R. J., J.P., M.R.I.A. 78 Kenilworth-square, Rathgar. Co. Dublin.
1900. *Monckton, H. W., Treas.L.S., F.G.S. 3 Harcourt-buildings, Temple, E.C.
1905. *Moncrieff, Colonel Sir C. Scott, G.C.S.I., K.C.M.G., R.E. (Pres G, 1905.) 11 Cheyne-walk, S.W.
1905. ‡Moncrieff, Lady Scott. 11 Cheyne-walk, S.W.
1891. *Mond, Robert Ludwig, M.A., F.R.S.E., F.G.S. 20 Avenue-road, Regent's Park, N.W.
1909. §Moody, A. W., M.D. 430½ Main-street, Winnipeg, Canada.
1909. §Moody, G. T., D.Sc. Lorne House, Dulwich, S.E.
1905. ‡*Moore, Charles Elliott. P.O. Box* 5382, *Johannesburg.*
1908. *Moore, F. W. Royal Botanic Gardens, Glasnevin, Dublin.
1894. ‡Moore, Harold E. Oaklands, The Avenue, Beckenham, Kent.
1908. §Moore, Sir John W., M.D. 40 Fitzwilliam-square West, Dublin.
1901. *Moore, Robert T. 142 St. Vincent-street, Glasgow.
1905. §Moore, T. H. Thornhill Villa, Marsh, Huddersfield.
1896. *Mordey, W. M. 82 Victoria-street, S.W.

Year of Election.

1905. ‡More, T. E. Padern. Carlton Buildings, Parliament-street, Cape Town.
1901. *Moreno, Francisco P. Paraná 915, Buenos Aires.
1905. *Morgan, Miss Annie. Friedrichstrasse No. 2, Vienna.
1895. ‡MORGAN, C. LLOYD, F.R.S., F.G.S., Principal of University College, Bristol.
1896. ‡*Morgan, George.* 21 *Upper Parliament-street, Liverpool.*
1902. ‡MORGAN, GILBERT T., D.Sc., F.I.C. Royal College of Science, S.W.
1902. *Morgan, Septimus Vaughan. 37 Harrington-gardens, S.W.
1901. *Morison, James. Perth.
1883. *MORLEY, HENRY FORSTER, M.A., D.Sc., F.C.S. 5 Lyndhurst-road, Hampstead, N.W.
1906. ‡Morrell, H. R. Scarcroft-road, York.
1896. ‡Morrell, R. S. Caius College, Cambridge.
1908. ‡Morris, E. A. Montmorency, M.A., M.R.I.A. Winton House, Cabra, Co. Dublin.
1905. ‡Morris, F., M.B., B.Sc. 18 Hope-street, Cape Town.
1896. *Morris, J. T. 47 Cumberland-mansions, Seymour-place, W.
1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1907. ‡Morris, Colonel Sir W. G., K.C.M.G. Care of Messrs. Cox & Co., 16 Charing Cross, W.C.
1899. *MORROW, JOHN, M.Sc., D.Eng. Armstrong College, Newcastle-upon-Tyne.
1909. §Morse, Morton F. Wellington-crescent, Winnipeg, Canada.
1865. ‡Mortimer, J. R. St. John's Villas, Driffield.
1886. *Morton, P. F. 15 Ashley-place, Westminster, S.W.
1896. *MORTON, WILLIAM B., M.A., Professor of Natural Philosophy in Queen's College, Belfast.
1908. ‡Moss, Dr. C. E. Botany School, Cambridge.
1876. §MOSS, RICHARD JACKSON, F.I.C., M.R.I.A. Royal Dublin Society, and St. Aubyn's, Ballybrack, Co. Dublin.
1892. *Mostyn, S. G., M.A., M.B. 15 Grange-avenue, Harton, near South Shields.
1878. *MOULTON, The Right Hon. Lord Justice, M.A., K.C., F.R.S. 57 Onslow-square, S.W.
1899. §Mowll, Martyn. Chaldercot, Leyburne-road, Dover.
1905. ‡Moylan, Miss V. C. 3 Canning-place, Palace Gate, W.
1905. *Moysey, Miss E. L. Pitcroft, Guildford, Surrey.
1902. §Muir, Arthur H. 2 Wellington-place, Belfast.
1907. *Muir, Professor James. 31 Burnbank-gardens, Glasgow.
1874. ‡MUIR, M. M. PATTISON, M.A. Gonville and Caius College, Cambridge.
1909. §Muir, Robert R. Grain Exchange-building, Winnipeg, Canada.
1904. §Muir, William. Rowallan, Newton Stewart, N.B.
1872. *MUIRHEAD, ALEXANDER, D.Sc., F.R.S., F.C.S. 12 Carteret-street, Queen Anne's Gate, Westminster, S.W.
1905. *Muirhead, James M. P., F.R.S.E. Markham's-chambers, St. George's-street, Cape Town.
1876. *Muirhead, Robert Franklin, B.A., D.Sc. 64 Great George-street, Hillhead, Glasgow.
1902. ‡Mullan, James. Castlerock, Co. Derry.
1884. *MÜLLER, HUGO, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, N.W.
1905. ‡Mulligan, A. 'Natal Mercury' Office, Durban, Natal.
1908. ‡MULLIGAN, JOHN. (Local Sec. 1908.) Greinan, Adelaide-road, Kingstown, Co. Dublin.
1904. §Mullinger, J. Bass, M.A. 1 Bene't-place, Cambridge.

Year of Election.

1898. ‡Mumford, C. E. Cross Roads House, Bouveric-road, Folkestone.
1901. *Munby, Alan E. Royal Societies Club, St. James's-street, S.W.
Munby, Arthur Joseph. 6 Fig Tree-court, Temple, E.C.
1906. ‡Munby, Frederick J. Whixley, York.
1904. ‡Munro, A. Queens' College, Cambridge.
1909. §Munro, George. 188 Roslyn-road, Winnipeg, Canada.
1883. *MUNRO, ROBERT, M.A., M.D., LL.D. (Pres. H, 1893.) Elmbank, Largs, Ayrshire, N.B.
1909. §Munson, J. H., K.C. Wellington-crescent, Winnipeg, Canada.
1890. ‡Murphy, A. J. Springfield Mount, Leeds.
1909. §Murphy, A. J. Vanguard Manufacturing Co., Dorrington-street, Leeds.
1908. ‡Murphy, Leonard. 156 Richmond-road, Dublin.
1908. ‡MURPHY, WILLIAM M., J.P. Dartry, Dublin.
1905 ‡Murray, Charles F. K., M.D. Kenilworth House, Kenilworth, Cape Colony.
1905. ‡Murray, Dr. F. Londinium, London-road, Sea Point, Cape Town.
1891. ‡MURRAY, G. R. M., F.R.S., F.R.S.E., F.L.S. 32 Market-square, Stonehaven, N.B.
1905. §Murray, Sir James, LL.D., Litt.D. Sunnyside, Oxford.
1905. §Murray, Lady. Sunnyside, Oxford.
1884. ‡MURRAY, Sir JOHN, K.C.B., LL.D., D.Sc., Ph.D., F.R.S., F.R.S.E. (Pres. E, 1899.) Challenger Lodge, Wardie, Edinburgh.
1903. §Murray, Colonel J. D. Rowbottom-square, Wigan.
1909. §Murray, W. C. University of Saskatchewan, Saskatoon, Saskatchewan, Canada.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1902. ‡Myddleton, Alfred. 62 Duncairn-street, Belfast.
1902. *Myers, Charles S., M.A., M.D. Great Shelford, Cambridge.
1909. *Myers, Henry. The Long House, Leatherhead.
1906. ‡Myers, Jesse A. Glengarth, Walker-road, Harrogate.
1890. *MYRES, JOHN L., M.A., F.S.A. (Pres. H, 1909; Council, 1909–), Professor of Greek in the University of Liverpool. 26 Abercromby-square, Liverpool.

1886. ‡NAGEL, D. H., M.A. (Local Sec. 1894.) Trinity College, Oxford.
1892. *Nairn, Sir Michael B., Bart. Kirkcaldy, N.B.
1890. ‡Nalder, Francis Henry. 34 Queen-street, E.C.
1908. ‡Nally, T. H. Temple Hill, Terenure, Co. Dublin.
1905. ‡Napier, Dr. Francis. 73 Jeppe-street, Von Brandis-square, Johannesburg.
1872. ‡NARES, Admiral Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 11 Claremont-road, Surbiton.
1909. §Neild, Frederic, M.D. Mount Pleasant House, Tunbridge Wells.
1883. *Neild, Theodore, M.A. Grange Court, Leominster.
1898. *Nevill, Rev. J. H. N., M.A. The Vicarage, Stoke Gabriel, South Devon.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. ‡NEVILLE, F. H., M.A., F.R.S. Sidney College, Cambridge.
1889. *Newall, H. Frank, M.A., F.R.S., F.R.A.S. Madingley Rise, Cambridge.
1901. ‡Newman, F. H. Tullie House, Carlisle.
1889. ‡Newstead, A. H. L., B.A. 38 Green-street, Bethnal Green, N.E.

Year of Election.

1892. ‡NEWTON, E. T., F.R.S., F.G.S. Florence House, Willow Bridge-road, Canonbury, N.
1908. ‡Nicholls, W. A. 11 Vernham-road, Plumstead, Kent.
1908. ‡Nichols, Albert Russell. 30 Grosvener-square, Rathmines, Co. Dublin.
1887. ‡Nicholson, John Carr, J.P. Moorfield House, Headingley, Leeds.
1884. ‡NICHOLSON, JOSEPH S., M.A., D.Sc. (Pres. F, 1893), Professor of Political Economy in the University of Edinburgh. Eden Lodge, Newbattle-terrace, Edinburgh.
1908. §Nicholson, J. W. Trinity College, Cambridge.
1908. ‡NIXON, Sir CHRISTOPHER, Bart., M.D., LL.D., D.L. 2 Merrion-square, Dublin.
1863. *NOBLE, Sir ANDREW, Bart., K.C.B., D.Sc., F.R.S., F.R.A.S., F.C.S. (Pres. G, 1890; Council, 1903–06; Local Sec. 1863.) Elswick Works, and Jesmond Dene House, Newcastle-upon-Tyne.
1863. §NORMAN, Rev. Canon ALFRED MERLE, M.A., D.C.L., LL.D., F.R.S., F.L.S. The Red House, Berkhamsted.
1888. ‡Norman, George. 12 Brock-street, Bath.
1883. *Norris, William G. Dale House, Coalbrookdale, R.S.O., Shropshire.
1894. §NOTCUTT, S. A., LL.M., B.A., B.Sc. (Local Sec. 1895.) Constitution-hill, Ipswich.
1903. ‡Noton, John. 45 Part-street, Southport.
1909. §Nugent, F. S. 81 Notre Dame-avenue, Winnipeg, Canada.
1908. §Nutting, Sir John, Bart. St. Helen's, Co. Dublin.

1898. *O'Brien, Neville Forth. Fryth, Pyrford, Surrey.
1908. ‡O'Carroll, Joseph, M.D. 43 Merrion-square East, Dublin.
1883. ‡Odgers, William Blake, M.A., LL.D., K.C. 15 Old-square, Lincoln's Inn, W.C.
1858. *ODLING, WILLIAM, M.B., F.R.S., V.P.C.S. (Pres. B, 1864; Council, 1865–70), Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1908. §O'Farrell, Thomas A. 30 Lansdowne-road, Dublin.
1902. ‡Ogden, James Neal. Claremont, Heaton Chapel, Stockport.
1876. ‡Ogilvie, Campbell P. Lawford-place, Manningtree.
1885. ‡OGILVIE, F. GRANT, C.B., M.A., B.Sc., F.R.S.E. (Local Sec. 1892.) Board of Education, S.W.
1905. *Oke, Alfred William, B.A., LL.M., F.G.S., F.L.S. 32 Denmark-villas, Hove, Brighton.
1905. §Okell, Samuel, F.R.A.S. Overley, Langham-road, Bowdon, Cheshire.
1908. §Oldham, Charles Hubert, B.A., B.L., Professor of Commerce in the National University of Ireland. 5 Victoria-terrace, Rathgar, Dublin.
1892. ‡OLDHAM, H. YULE, M.A., F.R.G.S., Lecturer in Geography in the University of Cambridge. King's College, Cambridge.
1893. *OLDHAM, R. D., F.G.S., Geological Survey of India. Care of Messrs. H. S. King & Co., 9 Pall Mall, S.W.
1863. ‡OLIVER, DANIEL, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew, Surrey.
1887. ‡OLIVER, F. W., D.Sc., F.R.S., F.L.S. (Pres. K, 1906), Professor of Botany in University College, London. 137 Church-street, Chelsea, S.W.
1889. ‡Oliver, Professor Sir Thomas, M.D. 7 Ellison-place, Newcastle-upon-Tyne.

Year of Election.

1882. §Olsen, O. T., D.Sc., F.L.S., F.R.A.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
1880. *Ommanney, Rev. E. A. St. Michael's and All Angels, Portsea, Hants.
1908. ‡O'Neill, Rev. G., M.A. University College, St. Stephen's Green, Dublin.
1902. ‡O'Neill, Henry, M.D. 6 College-square East, Belfast.
1902. ‡O'Reilly, Patrick Joseph. 7 North Earl-street, Dublin.
1905. ‡O'Riley, J. C. 70 Barnet-street, Gardens, Cape Town.
1884. *Orpen, Rev. T. H., M.A. The Vicarage, Great Shelford, Cambridge.
1901. ‡Orr, Alexander Stewart. Care of Messrs. Marsland, Price, & Co., Nesbit-road, Mazagon, Bombay, India.
1905. ‡Orr, Professor John. Transvaal Technical Institute, Johannesburg.
1909. §Orr, John B. Crossacres, Woolton, Liverpool.
1908. *Orr, William. Dungarvan, Co. Waterford.
1904. *Orton, K. J. P., M.A., Ph.D., Professor of Chemistry in University College, Bangor.
1905. ‡Osborn, Philip B. P.O. Box 4181, Johannesburg.
1901. ‡Osborne, W. A., D.Sc. University College, W.C.
1908. ‡O'Shaughnessy, T. L. 64 Fitzwilliam-square, Dublin.
1887. ‡O'Shea, L. T., B.Sc. University College, Sheffield.
1865. *Osler, Henry F. Coppy-hill, Linthurst, near Bromsgrove, Birmingham.
1884. ‡Osler, William, M.D., LL.D., F.R.S., Regius Professor of Medicine in the University of Oxford. University Museum, Oxford.
1881. *Ottewell, Alfred D. 14 Mill Hill-road, Derby.
1896. ‡Oulton, W. Hillside, Gateacre, Liverpool.
1906. ‡Owen, Rev. E. C. St. Peter's School, York.
1903. *Owen, Edwin, M.A. Terra Nova School, Birkdale, Lancashire.
1889. **Owen, Alderman, H. C. Compton, Wolverhampton.*
1896. ‡Owen, Peter. The Elms, Capenhurst, Chester.

1909. §Pace, F. W. 388 Wellington-crescent, Winnipeg, Canada.
1908. ‡Pack-Beresford, Denis, M.R.I.A. Fenagh House, Bagenalstown, Ireland.
1906. §Page, Carl D. Wyoming House, Aylesbury, Bucks.
1903. *Page, Miss Ellen Iva. Turret House, Felpham, Sussex.
1870. *Palgrave, Sir Robert Harry Inglis, F.R.S., F.S.S. (Pres. F, 1883.) Henstead Hall, Wrentham, Suffolk.
1896. ‡Pallis, Alexander. Tatoi, Aigburth-drive, Liverpool.
1878. *Palmer, Joseph Edward. Royal Societies Club, St. James's-street, S.W.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
1880. *Parke, George Henry, F.L.S., F.G.S. Care of W. T. Cooper, Esq., Aysgarth, The Mall, Southgate, N.
1904. ‡Parker, E. H., M.A. Thorneycreek, Herschel-road, Cambridge.
1905. ‡Parker, Hugh. P.O. Box 200, Pietermaritzburg, Natal.
1905. ‡Parker, John. 37 Hout-street, Cape Town.
1909. §Parker, M. A., B.Sc., F.C.S. (Local Sec. 1909), Professor of Chemistry in the University of Manitoba, Winnipeg, Canada.
1891. ‡Parker, William Newton, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1905. *Parkes, Tom E. P.O. Box 4580, Johannesburg.
1899. *Parkin, John. Blaithwaite, Carlisle.
1905. *Parkin. Thomas. Blaithwaite, Carlisle.

Year of
Election.

1906. §Parkin, Thomas, M.A., F.Z.S., F.R.G.S. Fairseat, High Wickham, Hastings.
1879. *Parkin, William. The Mount, Sheffield.
1903. ‡Parry, Joseph, M.Inst.C.E. Woodbury, Waterloo, near Liverpool.
1908. ‡Parry, W. K., M.Inst.C.E. 6 Charlemont-terrace, Kingstown, Dublin.
1878. ‡PARSONS, Hon. C. A., C.B., M.A., Sc.D., F.R.S., M.Inst.C.E. (Pres. G, 1904.) Holeyn Hall, Wylam-on-Tyne.
1904. ‡Parsons, Professor F. G. St. Thomas's Hospital, S.E.
1905. *Parsons, Hon. Geoffrey L. Northern Counties Club, Newcastle-on-Tyne.
1898. *Partridge, Miss Josephine M. 15 Grosvenor-crescent, S.W.
1887. ‡PATERSON, A. M., M.D., Professor of Anatomy in the University of Liverpool.
1908. ‡Paterson, M., LL.D. 7 Halton-place, Edinburgh.
1909. §Paterson, William. Ottawa, Canada.
1897. ‡Paton, D. Noël, M.D. Physiological Laboratory, The University, Glasgow.
1883. *Paton, Rev. Henry, M.A. 120 Polwarth-terrace, Edinburgh.
1884. *Paton, Hugh. Box 2400, Montreal, Canada.
1908. §Patten, C. J., M.A., M.D., Sc.D. The University, Sheffield.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1879. *Patzer, F. R. Clayton Lodge, Newcastle, Staffordshire.
1883. ‡Paul, George. 32 Harlow Moor-drive, Harrogate.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., LL.D., F.R.S. 35 Grosvenor-street, W.
1887. *Paxman, James. Standard Iron Works, Colchester.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1877. *Payne, J. C. Charles, J.P. Albion-place, The Plains, Belfast.
1881. ‡Payne, Mrs. Albion-place, The Plains, Belfast.
1888. *Paynter, J. B. Hendford Manor, Yeovil.
1876. ‡Peace, G. H., M.Inst.C.E. Monton Grange, Eccles, near Manchester.
1906. ‡Peace, Miss Gertrude. 39 Westbourne-road, Sheffield.
1885. ‡PEACH, B. N., F.R.S., F.R.S.E., F.G.S. Geological Survey Office, Edinburgh.
1886. *Pearce, Mrs. Horace. Collingwood, Manby-road, West Malvern.
1905. ‡Pearse, S. P.O. Box 149, Johannesburg.
1883. ‡Pearson, Arthur A., C.M.G. Hillsborough, Heath-road, Petersfield, Hampshire.
1893. *Pearson, Charles E. Hillcrest, Lowdham, Nottinghamshire.
1898. §Pearson, George. Bank-chambers, Baldwin-street, Bristol.
1905. §Pearson, Professor H. H. W., M.A., F.L.S. South African College, Cape Town.
1883. ‡*Pearson, Miss Helen E. Oakhurst, Birkdale, Southport.*
1906. §Pearson, Joseph. The University, Liverpool.
1904. ‡Pearson, Karl, M.A., F.R.S., Professor of Applied Mathematics in University College, London, W.C.
1909. §Pearson, William. Wellington-crescent, Winnipeg, Canada.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *PECKOVER, Lord, LL.D., F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1885. ‡Peddie, William, Ph.D., F.R.S.E., Professor of Natural Philosophy in University College, Dundee.

Year of Election.

1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1878. *Peek, William. Dorman's Park, near East Grinstead.
1901. *Peel, Hon. William, M.P. 13 King's Bench-walk, Temple, E.C.
1905. §Peirson, J. Waldie. P.O. Box 561, Johannesburg.
1905. §Pemberton, Gustavus M. P.O. Box 93, Johannesburg.
1887. ‡PENDLEBURY, WILLIAM H., M.A., F.C.S. (Local Sec. 1899.) Woodford House, Mountfields, Shrewsbury.
1894. ‡Pengelly, Miss. Lamorna, Torquay.
1896. ‡Pennant, P. P. Nantlys, St. Asaph.
1898. ‡Pentecost, Rev. Harold, M.A. The School, Giggleswick, Yorkshire.
1898. ‡Percival, Francis W., M.A., F.R.G.S. 1 Chesham-street, S.W.
1908. ‡Percival, Professor John, M.A. University College, Reading.
1905. ‡Péringuey, L., D.Sc., F.Z.S. South African Museum, Cape Town.
1894. ‡PERKIN, A. G., F.R.S., F.R.S.E., F.C.S., F.I.C. 8 Montpelier-terrace, Hyde Park, Leeds.
1902. *Perkin, F. Mollwo, Ph.D. The Firs, Hengrave-road, Honor Oak Park, S.E.
1884. ‡PERKIN, WILLIAM HENRY, LL.D., Ph.D., F.R.S., F.R.S.E. (Pres. B, 1900; Council, 1901–07), Professor of Organic Chemistry in the Victoria University, Manchester. Fairview, Wilbraham-road, Fallowfield, Manchester.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1898. *Perman, E. P., D.Sc. University College, Cardiff.
1909. §Perry, Rev. Professor E. Guthrie. 246 Kennedy-street, Winnipeg, Canada.
1874. *PERRY, JOHN, M.E., D.Sc., LL.D., F.R.S. (GENERAL TREASURER, 1904– ; Pres. G, 1902; Council, 1901–04), Professor of Mechanics and Mathematics in the Imperial College of Science, S.W.
1904. *Pertz, Miss D. F. M. 2 Cranmer-road, Cambridge.
1900. *Petavel, J. E., M.Sc., F.R.S., Professor of Engineering in the University of Manchester.
1901. ‡Pethybridge, G. H. Royal College of Science, Dublin.
1895. ‡PETRIE, W. M. FLINDERS, D.C.L., F.R.S. (Pres. H, 1895), Professor of Egyptology in University College, W.C.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. Vale House, St. Helier's, Jersey.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, S.W.
1903. ‡Philip, James C. 20 Westfield-terrace, Aberdeen.
1905. ‡Philip, John W. P.O. Box 215, Johannesburg.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1877. §Philips, T. Wishart. Elizabeth Lodge, Crescent-road, South Woodford, Essex.
1905. ‡Phillimore, Miss C. M. Shiplake House, Henley-on-Thames.
1899. *Phillips, Charles E. S., F.R.S.E. Castle House, Shooter's Hill, Kent.
1894. ‡Phillips, Staff-Commander E. C. D., R.N., F.R.G.S. 14 Hargreaves-buildings, Chapel-street, Liverpool.
1902. ‡Phillips, J. St. J., B.E. 64 Royal-avenue, Belfast.
1890. ‡Phillips, R. W., M.A., D.Sc., F.L.S., Professor of Botany in University College, Bangor. 2 Snowdon-villas, Bangor.
1909. *Phillips, Richard. 15 Dogpole, Shrewsbury.
1905. ‡Phillp, Miss M. E. de R., B.Sc. 12 Crescent-grove, Clapham, S.W.
1883. *Pickard, Joseph William. Oatlands, Lancaster.
1901. §Pickard, Robert H., D.Sc. Isca, Merlin-road, Blackburn.
1885. *PICKERING, SPENCER P. U., M.A., F.R.S. Harpenden, Herts.

Year of Election.

1884. *Pickett, Thomas E., M.D. Maysville, Mason Co., Kentucky, U.S.A.
1907. ‡Pickles, A. R., M.A. Todmorden-road, Burnley.
1888. *Pidgeon, W. R. Lynsted Lodge, St. Edmund's-terrace, Regent's Park, N.W.
1865. ‡PIKE, L. OWEN. 10 Chester-terrace, Regent's Park, N.W.
1896. *Pilkington, A. C. Rocklands, Rainhill, Lancashire.
1905. ‡Pilling, Arnold. Royal Observatory, Cape Town.
1896. *Pilling, William. Rosario, Heene-road, West Worthing.
1905. ‡Pim, Miss Gertrude. Charleville, Blackrock, Co. Dublin.
1908. *Pio, Professor D. A. 14 Leverton-street, Kentish Town, N.W.
1908. §Pirrie, The Right Hon. Lord, LL.D., M.Inst.C.E. Downshire House, Belgrave-square, S.W.
1909. §Pitblado, Isaac, K.C. 91 Balmoral-place, Winnipeg, Canada.
1893. *PITT, WALTER, M.Inst.C.E. Lansdown Grove Lodge, Bath.
1908. §Pixell, Miss Helen L. M. St. Faith's Vicarage, Stoke Newington, N.
1900. *Platts, Walter. Fairmount, Bingley.
1898. §Plummer, W. E., M.A., F.R.A.S. The Observatory, Bidston, Birkenhead.
1908. ‡Plunkett, Count G. N. National Museum of Science and Art, Dublin.
1908. ‡Plunkett, Colonel G. T., C.B. Belvedere Lodge, Wimbledon, S.W.
1907. *PLUNKETT, Right Hon. Sir HORACE, K.C.V.O., M.A., F.R.S. Kilteragh, Foxrock, Co. Dublin.
1900. *Pocklington, H. Cabourn, M.A., D.Sc., F.R.S. 11 Regent's Park-terrace, Leeds.
1904. ‡Pollard, William. 12 Aberdare-gardens, South Hampstead, N.W.
1908. ‡Pollok, James H., D.Sc. 6 St. James's-terrace, Clonshea, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1906. *Pontifex, Miss Catherine E. The Chestnuts, Mulgrave-road, Sutton, Surrey.
1907. §Pope, Alfred, F.S.A. South Court, Dorchester.
1900. *POPE, W. J., F.R.S., Professor of Chemistry in the University of Cambridge.
1892. ‡Popplewell, W. C., M.Sc., Assoc.M.Inst.C.E. Bowden-lane, Marple, Cheshire.
1901. §Porter, Alfred W., B.Sc. 87 Parliament Hill-mansions, Lissenden-gardens, N.W.
1883. *Porter, Rev. C. T., LL.D., D.D. All Saints' Vicarage, Southport.
1905. §PORTER, J. B., Ph.D., M.Inst.C.E., Professor of Mining Engineering in the McGill University, Montreal, Canada.
1905. ‡Porter, Mrs. McGill University, Montreal, Canada.
1883. ‡POTTER, M. C., M.A., F.L.S., Professor of Botany in the Armstrong College, Newcastle-upon-Tyne. 13 Highbury, Newcastle-upon-Tyne.
1906. ‡Potter-Kirby, Alderman George. Clifton Lawn, York.
1907. ‡Potts, F. A. University Museum of Zoology, Cambridge.
1908. *Potts, George, Ph.D., M.Sc. Grey University College, Bloemfontein, South Africa.
1886. *POULTON, EDWARD B., M.A., F.R.S., F.L.S., F.G.S., F.Z.S. (Pres. D, 1896; Council, 1895–1901, 1905–), Professor of Zoology in the University of Oxford. Wykeham House, Banbury-road, Oxford.
1905. ‡Poulton, Mrs. Wykeham House, Banbury-road, Oxford.
1898. *Poulton, Edward Palmer, M.A. Wykeham House, Banbury-road, Oxford.
1905. ‡Poulton, Miss. Wykeham House, Banbury-road, Oxford.

Year of
Election.

1905. ‡Poulton, Miss M. Wykeham House, Banbury-road, Oxford.
1873. *Powell, Sir Francis S., Bart., M.P., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, W.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 62 Wimpole-street, Cavendish-square, W.
1887. §Pownall, George H. 20 Birchin-lane, E.C.
1883. ‡POYNTING, J. H., D.Sc., F.R.S. (Pres. A, 1899), Professor of Physics in the University of Birmingham. 10 Ampton-road, Edgbaston, Birmingham.
1908. ‡Praeger, R. Lloyd, B.A., M.R.I.A. Lisnamae, Rathgar, Dublin.
1907. *PRAIN, Lieut.-Col. DAVID, C.I.E., M.B., F.R.S. (Pres. K, 1909; Council, 1907– .) Royal Gardens, Kew.
1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1906. ‡Pratt, Miss Edith M., D.Sc. The Woodlands, Silverdale, Lancashire.
1869. *PREECE, Sir WILLIAM HENRY, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1888; Council, 1888–95, 1896–1902.) Gothic Lodge, Wimbledon Common, S.W.
1888. *Preece, W. Llewellyn. Bryn Helen, Woodborough-road, Putney, S.W.
1904. §Prentice, Mrs. Manning. Thelema, Undercliff-road, Felixstowe.
1892. ‡Prentice, Thomas. Willow Park, Greenock.
1910. §PRESCOTT, R. M. (Local Sec., 1910.) Town Hall, Sheffield.
1906. ‡Pressly, D. L. Coney-street, York.
1889. ‡Preston, Alfred Eley, M.Inst.C.E., F.G.S. 14 The Exchange, Bradford, Yorkshire.
1903. §Price, Edward E. Oaklands, Oaklands-road, Bromley, Kent.
1888. ‡PRICE, L. L. F. R., M.A., F.S.S. (Pres. F, 1895; Council, 1898-1904.) Oriel College, Oxford.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1897. *PRICE, W. A., M.A. 38 Gloucester-road, Teddington.
1908. §Priestley, J. H. University College, Bristol.
1909. *Prince, Professor E. E. Ottawa, Canada.
1905. ‡Prince, James Perrott, M.D. Durban, Natal.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. 70 Fairhazel-gardens, South Hampstead, N.W.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 26 Wimpole-street, W.
1881. §Procter, John William. Ashcroft, York.
1884. *Proudfoot, Alexander, M.D. 100 State-street, Chicago, U.S.A.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Ilfracombe.
1907. §Pryce, George Arthur. Care of Philip Harris & Co., Limited, 144 Edmund-street, Birmingham.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1867. *Pullar, Sir Robert, M.P., F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Brahan, Perth.
1903. ‡Pullen-Burry, Miss. 28 Fairholme-road, West Kensington, W.
1904. ‡Punnett, R. C. Caius College, Cambridge.
1905. ‡Purcell, W. F., M.A., Ph.D. South African Museum, Cape Town.
1905. ‡Purcell, Mrs. W. F. South African Museum, Cape Town.
1885. ‡PURDIE, THOMAS, B.Sc., Ph.D., F.R.S., Professor of Chemistry in the University of St. Andrews. 14 South-street, St. Andrews, N.B.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1874. ‡PURSER, FREDERICK, M.A. Rathmines Castle, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., LL.D., M.R.I.A. (Pres. A, 1902.) Rathmines Castle, Dublin.
1884. *Purves, W. Laidlaw. 20 Stratford-place, Oxford-street, W.
1905. ‡Purvis, Mr. P.O. Box 744, Johannesburg.

Year of Election.

1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1898. *Pye, Miss E. St. Mary's Hall, Rochester.
1883. §Pye-Smith, Arnold. 32 Queen Victoria-street, E.C.
1883. ‡Pye-Smith, Mrs. 32 Queen Victoria-street, E.C.
1868. ‡PYE-SMITH, P. H., M.D., F.R.S. 48 Brook-street, W.; and Guy's Hospital, S.E.
1879. ‡Pye-Smith, R. J. 350 Glossop-road, Sheffield.

1893. ‡Quick, James. 36 Kingsworth-gardens, Folkestone.
1906. *Quiggin, Mrs. A. Hingston. 88 Hartington-grove, Cambridge.

1855. *Radstock, The Right Hon. Lord. Mayfield, Woolston, Southampton.
1887. *Ragdale, John Rowland. The Beeches, Stand, near Manchester.
1905. ‡Raine, Miss. P.O. Box 788, Johannesburg.
1905. ‡Raine, Robert. P.O. Box 1091, Johannesburg.
1898. *Raisin, Miss Catherine A., D.Sc., Bedford College, York-place, Baker-street, W.
1896. *RAMAGE, HUGH, M.A. The Technical Institute, Norwich.
1894. *RAMBAUT, ARTHUR A., M.A., D.Sc., F.R.S., F.R.A.S., M.R.I.A. Radcliffe Observatory, Oxford.
1908. ‡Rambaut, Mrs. Radcliffe Observatory, Oxford.
1876. *RAMSAY, Sir WILLIAM, K.C.B., Ph.D., D.Sc., F.R.S. (Pres. B, 1897; Council, 1891–98), Professor of Chemistry in University College, London. 19 Chester-terrace, Regent's Park, N.W.
1883. ‡Ramsay, Lady. 19 Chester-terrace, Regent's Park, N.W.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, W.
1907. ‡Rankine, A. O. 21 Drayton-road, West Ealing, W.
1868. *Ransom, Edwin, F.R.G.S. 24 Ashburnham-road, Bedford.
1861. ‡RANSOME, ARTHUR, M.A., M.D., F.R.S. (Local Sec. 1861.) Sunnyhurst, Deane Park, Bournemouth.
1903. §Rastall, R. H. Christ's College, Cambridge.
1892. *Rathbone, Miss May. Backwood, Neston, Cheshire.
1874. ‡RAVENSTEIN, E. G., F.R.G.S., F.S.S. (Pres. E, 1891.) 2 York-mansions, Battersea Park, S.W.
1908. *Raworth, Alexander. Fairholm, Uppingham-road, Leicester.
1905. ‡Rawson, Colonel Herbert E., R.E. Army Headquarters, Pretoria.
1868. *RAYLEIGH, The Right Hon. Lord, O.M., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. (PRESIDENT, 1884; TRUSTEE, 1883– ; Pres. A, 1882; Council, 1878–83), Professor of Natural Philosophy in the Royal Institution, London. Terling Place, Witham, Essex.
1883. *Rayne, Charles A., M.D., M.R.C.S. St. Mary's Gate, Lancaster.
1897. *Rayner, Edwin Hartree, M.A. Elm Lodge, Queen's-road, Teddington, Middlesex.
1907. §Rea, Carleton, B.C.L. 34 Foregate-street, Worcester.
1896. *READ, CHARLES H., LL.D., F.S.A. (Pres. H, 1899.) British Museum, W.C.
1902. ‡Reade, R. H. Wilmount, Dunmurry.
1884. §Readman, J. B., D.Sc., F.R.S.E. Staffield Hall, Kirkoswald, R.S.O., Cumberland.
1852. *REDFERN, Professor PETER, M.D. (Pres. D, 1874.) Templepatrick House, Donaghadee, Co. Down.
1890. *Redwood, Sir Boverton, F.R.S.E., F.C.S. Wadham Lodge, Wadham-gardens, N.W.

Year of Election.

1908. §Reed, Sir Andrew, K.C.B., C.V.O., LL.D. 23 Fitzwilliam-square, Dublin.
1905. §Reed, J. Howard, F.R.G.S. 16 St. Mary's Parsonage, Manchester.
1891. *Reed, Thomas A. Bute Docks, Cardiff.
1894. *Rees, Edmund S. G. Dunsear, Oaken, near Wolverhampton.
1891. *Rees, I. Treharne, M.Inst.C.E. Blaenypant, near Newport, Monmouthshire.
1903. §Reeves, E. A., F.R.G.S. 1 Savile-row, W.
1906. *Reichel, Sir H. R., LL.D., Principal of University College, Bangor. Penrallt, Bangor, North Wales.
1901. *Reid, Andrew T. 10 Woodside-terrace, Glasgow.
1904. ‡Reid, Arthur H. 30 Welbeck-street, W.
1881. §Reid, Arthur S., M.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *REID, CLEMENT, F.R.S., F.L.S., F.G.S. 28 Jermyn-street, S.W.
1903. *Reid, Mrs. E. M., B.Sc. 7 St. James's-mansions, West End-lane, N.W.
1892. ‡REID, E. WAYMOUTH, B.A., M.B., F.R.S., Professor of Physiology in University College, Dundee.
1908. §REID, GEORGE ARCHDALL, M.B., C.M., F.R.S.E. 9 Victoria-road South, Southsea.
1901. *Reid, Hugh. Belmont, Springburn, Glasgow.
1901. ‡Reid, John. 7 Park-terrace, Glasgow.
1909. §Reid, John Young. 329 Wellington-crescent, Winnipeg, Canada.
1904. ‡Reid, P. J. Moor Cottage, Nunthorpe, R.S.O., Yorkshire.
1897. ‡Reid, T. Whitehead, M.D. St. George's House, Canterbury.
1909. §Reid, Walter A. Woodbank, Aberdeen.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1875. ‡REINOLD, A. W., M.A., F.R.S. (Council, 1890–95), Professor of Physics in the Royal Naval College, Greenwich, S.E.
1894. ‡Rendall, Rev. G. H., M.A., Litt.D. Charterhouse, Godalming.
1891. *Rendell, Rev. James Robson, B.A. Whinside, Whalley-road, Accrington.
1903. *RENDLE, Dr. A. B., M.A., F.R.S., F.L.S. 28 Holmbush-road, Putney, S.W.
1889. *Rennie, George B. 20 Lowndes-street, S.W.
1906. ‡Rennie, John, D.Sc. Natural History Department, University of Aberdeen.
1905. *Renton, James Hall. Rowfold Grange, Billinghurst, Sussex.
1905. ‡Reunert, Clive. Windybrow, Johannesburg.
1905. ‡Reunert, John. Windybrow, Johannesburg.
1904. ‡REUNERT, THEODORE, M.Inst.C.E. P.O. Box 92, Johannesburg.
1905. §Reyersbach, Louis. Care of Messrs. Wernher, Beit, & Co., 1 London Wall-buildings, E.C.
1883. *Reynolds, A. H. 271 Lord-street, Southport.
1871. ‡REYNOLDS, JAMES EMERSON, M.D., D.Sc., F.R.S., F.C.S., M.R.I.A. (Pres. B, 1893; Council, 1893–99.) 29 Campden Hill-court, W.
1900. *Reynolds, Miss K. M. 8 Darnley-road, Notting Hill, W.
1870. *REYNOLDS, OSBORNE, M.A., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1887.) St. Decuman's, Watchet, Somerset.
1906. ‡Reynolds, S. H., M.A., Professor of Geology and Zoology in University College, Bristol.
1907. §Reynolds, W. Birstall Holt, near Leicester.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1899. *RHYS, Professor Sir JOHN, D.Sc. (Pres. H, 1900.) Jesus College, Oxford.

Year of Election.

1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Riva Muro 14, Modena, Italy.
1905. §Rich, Miss Florence, M.A. Granville School, Granville-road, Leicester.
1906. ‡Richards, Rev. A. W. 12 Bootham-terrace, York.
1869. *Richardson, Charles. 3 Cholmley-villas, Long Ditton, Surrey.
1884. *Richardson, George Straker. Isthmian Club, Piccadilly, W.
1889. ‡Richardson, Hugh, M.A. 12 St. Mary's, York.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1896. *Richardson, Nelson Moore, B.A., F.E.S. Montevideo, Chickerell, near Weymouth.
1901. *Richardson, Professor Owen Willans. 25 Bank-street, Princetown, N.J., U.S.A.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1891. §*Riches, T. Hurry. 8 Park-grove, Cardiff.*
1883. *Rideal, Samuel, D.Sc., F.C.S. 28 Victoria-street, S.W.
1902. §Ridgeway, William, M.A., D.Litt., F.B.A. (Pres. H, 1908), Professor of Archæology in the University of Cambridge. Flendyshe, Fen Ditton, Cambridge.
1894. ‡Ridley, E. P., F.G.S. (Local Sec. 1895.) Burwood, Westerfield-road, Ipswich.
1881. *Rigg, Arthur. 150 Blomfield-terrace, W.
1883. *Rigg, Edward, I.S.O., M.A. Royal Mint, E.
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.
1905. ‡Ritchie, Professor W., M.A. South African College, Cape Town.
1903. *Rivers, W. H. R., M.D., F.R.S. St. John's College, Cambridge.
1908. *Roaf, Herbert E., M.D. Physiological Department, The University, Liverpool.
1898. *Robb, Alfred A. Lisnabreeny House, Belfast.
1902. *Roberts, Bruno. 30 St. George's-square, Regent's Park, N.W.
1887. *Roberts, Evan. 30 St. George's-square, Regent's Park, N.W.
1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. University of London, South Kensington, S.W.
1893. ‡Roberts, Thomas J. Ingleside, Park-road, Huyton, near Liverpool.
1904. *Robertson, Miss Agnes, D.Sc. 9 Elsworthy-terrace, Primrose Hill, N.W.
1897. §Robertson, Sir George S., K.C.S.I. (Pres. E, 1900.) 1 Pump-court, Temple, E.C.
1905. ‡Robertson, Dr. G. W. Office of the Medical Officer of Health, Cape Town.
1897. §Robertson, Professor J. W., C.M.G., LL.D. The Macdonald College, St. Anne de Bellevue, Quebec, Canada.
1901. *Robertson, Robert, B.Sc., M.Inst.C.E. 154 West George-street, Glasgow.
1905. ‡Robertson, Professor T. E. Transvaal Technical Institute, Johannesburg.
1898. ‡Robinson, Charles E., M.Inst.C.E. Holne Cross, Ashburton, South Devon.
1909. §Robinson, E. M. 381 Main-street, Winnipeg, Canada.
1903. ‡Robinson, G. H. 1 Weld-road, Southport.
1905. ‡Robinson, Harry. Duncan's-chambers, Shortmarket-street, Cape Town.
1887. §Robinson, Henry, M.Inst.C.E. Parliament-mansions, Victoria-street, S.W.
1902. ‡Robinson, Herbert C. Holmfield, Aigburth, Liverpool.
1906. ‡Robinson, H. H., M.A., F.I.C. 75 Finborough-road, S.W.
1902. ‡Robinson, James, M.A., F.R.G.S. Dulwich College, Dulwich, S.E.

Year of Election.

1888. ‡Robinson, John, M.Inst.C.E. 8 Vicarage-terrace, Kendal.
1908. *Robinson, John Gorges. Cragdale, Settle, Yorkshire.
1910. §Robinson, John Hargreaves. Cable Ship 'Norseman,' Western Telegraph Co., Caixa no Correu No. 117, Pernambuco, Brazil.
1895. *Robinson, Joseph Johnson. 8 Trafalgar-road, Birkdale, Southport.
1905. ‡Robinson, Dr. Leland. 6 Victoria-walk, Woodstock, Cape Town.
1899. *Robinson, Mark, M.Inst.C.E. 9 Belsize-grove, N.W.
1875. *Robinson, Robert, M.Inst.C.E. Beechwood, Darlington.
1908. ‡Robinson, Robert. Field House, Chesterfield.
1904. ‡Robinson, Theodore R. 25 Campden Hill-gardens, W.
1909. §Robinson, Captain W. 264 Roslyn-road, Winnipeg, Canada.
1909. §Robinson, Mrs. W. 264 Roslyn-road, Winnipeg, Canada.
1904. ‡Robinson, W. H. Kendrick House, Victoria-road, Penarth.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1906. §Robson, J. Nalton. The Villa, Hull-road, York.
1872. *Robson, William. 5 Gillsland-road, Merchiston, Edinburgh.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1885. *Rodriguez, Epifanio. New Adelphi Chambers, 6 Robert-street, Adelphi, W.C.
1905. ‡Roebuck, William Denison. 259 Hyde Park-road, Leeds.
1907. ‡Roechling, H. Alfred, M.Inst.C.E. 39 Victoria-street, S.W.
1908. §Rogers, A. G. L. Board of Agriculture and Fisheries, 8 Whitehall-place, S.W.
1905. §Rogers, A. W., M.A., F.G.S. South African Museum, Cape Town.
1898. ‡Rogers, Bertram, M.D. (Local Sec. 1898.) 11 York-place, Clifton, Bristol.
1907. ‡Rogers, John D. 85 St. George's-square, S.W.
1890. *Rogers, L. J., M.A., Professor of Mathematics in the University of Leeds. 15 Regent Park-avenue, Leeds.
1906. §Rogers, Reginald A. P. 142 Leinster-road, Dublin.
1909. §Rogers, Hon. Robert. Roslyn-road, Winnipeg, Canada.
1884. *Rogers, Walter. Lamorva, Falmouth.
1876. ‡Rollit, Sir A. K., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. 45 Belgrave-square, S.W.
1905. ‡Rooth, Edward. Pretoria.
1855. *Roscoe, The Right Hon. Sir Henry Enfield, B.A., Ph.D., LL.D., D.C.L., F.R.S. (President, 1887; Pres. B, 1870, 1884; Council, 1874–81; Local Sec. 1861.) 10 Bramham-gardens, S.W.
1905. ‡Rose, Miss G. 45 De Pary's-avenue, Bedford.
1905. ‡Rose, Miss G. Mabel. Ashley Lodge, Oxford.
1883. *Rose, J. Holland, Litt.D. Ethandune, Parkside-gardens, Wimbledon, S.W.
1905. ‡Rose, John G. Government Analytical Laboratory, Cape Town.
1894. *Rose, T. K., D.Sc., Chemist and Assayer to the Royal Mint. 6 Royal Mint, E.
1905. *Rosedale, Rev. H. G., D.D., F.S.A. St. Peter's Vicarage, 13 Ladbroke-gardens, W.
1905. *Rosedale, Rev. W. E., M.A. Willenhall, Staffordshire.
1905. ‡Rosen, Jacob. 1 Hopkins-street, Yeoville, Transvaal.
1905. ‡Rosen, Julius. Clifton Grange, Jarvie-street, Jeppestown, Transvaal.
1900. ‡Rosenhain, Walter, B.A. Park View, Park-road, Teddington.
1909. §Ross, D. A. 116 Wellington-crescent, Winnipeg, Canada.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1908. ‡Ross, Sir John, of Bladensburg, K.C.B. Rostrevor House, Rostrevor, Co. Down.
1902. ‡Ross, John Callender. 46 Holland-street, Campden-hill, W.

Year of Election.

1901. ‡Ross, Colonel RONALD, C.B., F.R.S., Professor of Tropical Medicine and Parasitology in the University of Liverpool. The University, Liverpool.
1891. *Roth, H. Ling. Briarfield, Shibden, Halifax, Yorkshire.
1905. ‡Rothkugel, R. Care of Messrs. D. Isaacs & Co., Cape Town.
1901. *Rottenburg, Paul, LL.D. Care of Messrs. Leister, Bock, & Co., Glasgow.
1899. *Round, J. C., M.R.C.S. 19 Crescent-road, Sydenham Hill, S.E.
1909. §Rounthwaite, C. H. E. Engineer's Office, Grand Trunk Pacific Railway, Canada, Winnipeg.
1884. *Rouse, M. L. Hollybank, Hayne-road, Beckenham.
1905. §Rousselet, Charles F. 2 Pembridge-crescent, Bayswater, W.
1883. ‡Rowan, Frederick John. 5 West Regent-street, Glasgow.
1903. *Rowe, Arthur W., M.B., F.G.S. 2 Price's-avenue, Margate.
1890. ‡Rowley, Walter, M.Inst.C.E., F.S.A. Alderhill, Meanwood, Leeds.
1881. *Rowntree, Joseph. 38 St. Mary's, York
1875. *RÜCKER, Sir ARTHUR W., M.A., D.Sc., F.R.S. (PRESIDENT, 1901; TRUSTEE, 1898– ; GENERAL TREASURER, 1891–98; Pres. A, 1894; Council, 1888–91.) Everington House, Newbury, Berkshire.
1869. §RUDLER, F. W., I.S.O., F.G.S. Ethel Villa, Tatsfield, Westerham.
1901. *Rudorf, C. C. G., Ph.D., B.Sc. Ivor, Cranley-gardens, Muswell Hill, N.
1905. *Ruffer, Marc Armand, C.M.G., M.A., M.D., B.Sc. Quarantine International Board, Alexandria.
1905. §Ruffer, Mrs. Alexandria.
1904. ‡Ruhemann, Dr. S. 3 Selwyn-gardens, Cambridge.
1909. §Rumball, Rev. M. C., B.A. Morden, Manitoba, Canada.
1896. *Rundell, T. W., F.R.Met.Soc. 3 Fenwick-street, Liverpool.
1904. ‡Russell, E. J., D.Sc., Rothamsted Experimental Station, Harpenden, Herts.
1875. *Russell, The Hon. F. A. R. Dunrozel, Haslemere.
Russell, John. 39 Mountjoy-square, Dublin.
1883. *Russell, J. W. 28 Staverton-road, Oxford.
1852. *Russell, Norman Scott. Arts Club, Dover-street, W.
1908. ‡Russell, Robert. Arduagremia, Haddon-road, Dublin.
1908. ‡RUSSELL, Right Hon. T. W., M.P. Olney, Terenure, Co. Dublin.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1909. *Rutherford, Alexander Cameron. Strathcona, Alberta, Canada.
1907. §RUTHERFORD, ERNEST, M.A., D.Sc., F.R.S. (Pres. A, 1909), Professor of Physics in the University of Manchester.
1909. §Ruttan, Colonel H. N. Armstrong's Point, Winnipeg, Canada.
1908. ‡Ryan, Hugh, D.Sc. Omdurman, Orwell Park, Rathgar, Dublin.
1905. ‡Ryan, Pierce. Rosebank House, Rosebank, Cape Town.
1909. §Ryan, Thomas. Assiniboine-avenue, Winnipeg, Canada.
1898. ‡Ryland, C. J. Southerndown House, Clifton, Bristol.
1906. *RYMER, Sir JOSEPH SYKES. The Mount, York.

1903. ‡SADLER, M. E., LL.D. (Pres. L, 1906), Professor of Education in the Victoria University, Manchester. Eastwood, Weybridge.
1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. Church House, Westminster, S.W.
1903. ‡Sagar, J. The Poplars, Savile Park, Halifax.
1873. *Salomons, Sir David, Bart., F.G.S. Broomhill, Tunbridge Wells.

Year of Election.

1904. §SALTER, A. E., D.Sc., F.G.S. 12 Clifton-road, Brockley, S.E.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1901. ‡Samuel, John S., J.P., F.R.S.E. City Chambers, Glasgow.
1907. *Sand, Dr. Henry J. S. University College, Nottingham.
1907. ‡Sandars, Miss Cora B. Parkholme, Elm Park-gardens, S.W.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1896. §Saner, John Arthur, Assoc.M.Inst.C.E. Highfield, Northwich.
1896. ‡Saner, Mrs. Highfield, Northwich.
1892. ‡*Sang, William D. Tylehurst, Kirkcaldy, Fife.*
1903. ‡Sankey, Captain H. R., R.E., M.Inst.C.E. Palace-chambers, 9 Bridge-street, S.W.
1886. ‡Sankey, Percy E. 44 Russell-square, W.C.
1905. ‡Sargant, E. B. Quarry Hill, Reigate.
1896. *Sargant, Miss Ethel. Quarry Hill, Reigate.
1905. ‡Sargent, Miss Helen A., B.A. Huguenot College, Wellington, Cape Colony.
1907. §Sargent, H. C. Ambergate, near Derby.
1886. ‡Saundby, Robert, M.D. 83A Edmund-street, Birmingham.
1900. *SAUNDER, S. A. Fir Holt, Crowthorne, Berks.
1903. *Saunders, Miss E. R. Newnham College, Cambridge.
1901. ‡Sawers, W. D. 1 Athole Gardens-place, Glasgow.
1887. §SAYCE, Rev. A. H., M.A., D.D. (Pres. H, 1887), Professor of Assyriology in the University of Oxford. Queen's College, Oxford.
1906. ‡Sayer, Dr. Ettie. 35 Upper Brook-street, W.
1883. *Scarborough, George. Whinney Field, Halifax, Yorkshire.
1903. §SCARISBRICK, Sir CHARLES, J.P. Scarisbrick Lodge, Southport.
1903. ‡Scarisbrick, Lady. Scarisbrick Lodge, Southport.
1879. *SCHÄFER, E. A., LL.D., D.Sc., F.R.S., M.R.C.S. (GENERAL SECRETARY, 1895–1900; Pres. I, 1894; Council, 1887–93), Professor of Physiology in the University of Edinburgh.
1888. *SCHARFF, ROBERT F., Ph.D., B.Sc., Keeper of the Natural History Department, National Museum, Dublin.
1880. *Schemmann, Louis Carl. Neueberg 12, Hamburg.
1885. ‡Scholes, L. Ivy Cottage, Parade, Parkgate, Cheshire.
1905. ‡Schonland, S., Ph.D. Albany Museum, Grahamstown, Cape Colony.
1908. §Schrödter, Dr. E. 3–5 Jacobistrasse, Düsseldorf, Germany.
1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S. (Pres. A, 1892; Council, 1887–93.) Kent House, Victoria Park, Manchester.
1905. ‡Sclander, J. E. P.O. Box 465, Cape Town.
1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S. (GENERAL SECRETARY, 1876–81; Pres. D, 1875; Council, 1864–67, 1872–75.) Odiham Priory, Winchfield.
1883. *SCLATER, W. LUTLEY, M.A., F.Z.S. Odiham Priory, Winchfield.
1905. ‡Sclater, Mrs. W. L. Odiham Priory, Winchfield.
1881. *SCOTT, ALEXANDER, M.A., D.Sc., F.R.S., F.C.S. Royal Institution, Albemarle-street, W.
1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1889. *SCOTT, D. H., M.A., Ph.D., F.R.S., Pres.L.S. (GENERAL SECRETARY, 1900–03; Pres. K, 1896.) East Oakley House, Oakley, Hants; and Athenæum Club, Pall Mall, S.W.
1857. *SCOTT, ROBERT H., M.A., D.Sc., F.R.S., F.R.Met.S. 6 Elm Park-gardens, S.W.
1884. **Scott, Sydney C. 28 The Avenue, Gipsy Hill, S.E.*
1902. ‡Scott, William R. The University, St. Andrews, Scotland.

Year of Election.

1895. ‡Scott-Elliot, Professor G. F., M.A., B.Sc., F.L.S. Newton, Dumfries.
1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1909. §Scudamore, Colonel F. W. Chelsworth Hall, Suffolk.
1895. ‡Scull, Miss E. M. L. St. Edmund's, 10 Worsley-road, Hampstead, N.W.
1890. *Searle, G. F. C., M.A., F.R.S. Wyncote, Hills-road, Cambridge.
1880. ‡Sedgwick, Adam, M.A., F.R.S. (Pres. D, 1899.) 4 Cranmer-road, Cambridge.
1905. ‡Sedgwick, C. F. Strand-street, Cape Town.
1906. *See, T. J. J., A.M., Ph.D., F.R.A.S., Professor of Mathematics, U.S. Navy. Naval Observatory, Mare Island, California.
1907. §Seligman, Dr. C. G. 15 York-terrace, Regent's Park, N.W.
1904. ‡Sell, W. J. 19 Lensfield-road, Cambridge.
1909. §Sellars, H. Lee. 225 Fifth-avenue, New York, U.S.A.
1888. *Senier, Alfred, M.D., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.
1888. *Sennett, Alfred R., A.M.Inst.C.E. Duffield, near Derby.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1905. ‡Serrurier, Louis C. Ashley, Sea Point, Cape Town.
1901. ‡Service, Robert. Janefield Park, Maxwelltown, Dumfries.
1895. *Seton-Karr, H. W. 31 Lingfield-road, Wimbledon, Surrey.
1892. *Seward, A. C., M.A., F.R.S., F.G.S. (Pres. K, 1903; Council, 1901–07; Local Sec. 1904), Professor of Botany in the University of Cambridge. Westfield, Huntingdon-road, Cambridge.
1904. ‡Sewell, R. B. Seymour. Christ's College, Cambridge.
1899. §Seymour, Professor Henry J., B.A., F.G.S. University College, Earlsfort-terrace, Dublin.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1905. *Shackleford, W. C., M.Inst.M.E. County Club, Lancaster.
1904. ‡Shackleton, Lieutenant Sir Ernest H., M.V.O., F.R.G.S. 14 South Learmonth-gardens, Edinburgh.
1902. ‡Shaftesbury, The Right Hon. the Earl of, D.L. Belfast Castle, Belfast.
1901. *Shakespear, Mrs. G. A. 21 Woodland-road, Northfield, Worcestershire.
1906. ‡Shann, Frederick. 6 St. Leonard's, York.
1878. ‡Sharp, David, M.A., M.B., F.R.S., F.L.S. Museum of Zoology, Cambridge.
1904. ‡Sharples, George. 181 Great Cheetham-street West, Higher Broughton, Manchester.
1889. *Shaw, Mrs. M. S., B.Sc. Brookhayes, Exmouth.
1883. *Shaw, W. N., M.A., Sc.D., F.R.S. (Pres. A, 1908; Council, 1895–1900, 1904–07.) Meteorological Office, 63 Victoria-street, S.W.
1883. ‡Shaw, Mrs. W. N. 10 Moreton-gardens, South Kensington, S.W.
1904. ‡Shaw-Phillips, Miss. 19 Camden-crescent, Bath.
1903. ‡Shaw-Phillips, T., J.P. 19 Camden-crescent, Bath.
1905. ‡Shenstone, Miss A. Sutton Hall, Barcombe, Lewes.
1905. ‡Shenstone, Mrs. A. E. G. Sutton Hall, Barcombe, Lewes.
1865. ‡Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
1900. §Sheppard, Thomas, F.G.S. The Municipal Museum, Hull.
1908. §Sheppard, W. F., Sc.D., LL.M. Board of Education, Whitehall, S.W.
1905. ‡Sheridan, Dr. Norman. 96 Francis-street, Bellevue, Johannesburg.
1883. ‡Sherlock, David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.

Year of Election.

1896. ‡SHERRINGTON, C. S., M.D., D.Sc., F.R.S. (Pres. I, 1904; Council, 1907–), Professor of Physiology in the University of Liverpool. 16 Grove-park, Liverpool.
1888. *Shickle, Rev. C. W., M.A., F.S.A. St. John's Hospital, Bath.
1908. *Shickle, Miss Mabel G. M. 9 Cavendish-crescent, Bath.
1902. *Shillington, T. Foulkes, J.P. Dromart, Antrim-road, Belfast.
1883. *Shillitoe, Buxton, F.R.C.S. 29 Sydenham-hill, S.E.
1887. *SHIPLEY, ARTHUR E., M.A., D.Sc., F.R.S. (Pres. D, 1909; Council, 1904– .) Christ's College, Cambridge.
1909. §Shipley, J. W., B.A. University of Manitoba, Winnipeg, Canada.
1897. ‡SHORE, Dr. LEWIS E. St. John's College, Cambridge.
1882. ‡SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital. 6 Kingswood-road, Upper Norwood, S.E.
1901. ‡Short, Peter M., B.Sc. 1 Holmdene-avenue, Herne Hill, S.E.
1908. §Shorter, Lewis R., B.Sc. 55 Campden Hill-road, W.
1904. *Shrubsall, F. C., M.A., M.D. 34 Lime-grove, Uxbridge-road, W.
1889. ‡Sibley, Walter K., M.A., M.D. The Mansions, 70 Duke-street, W.
1902. ‡Siddons, A. W. Harrow-on-the-Hill, Middlesex.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1877. *Sidebotham, Joseph Watson. Merlewood, Bowdon, Cheshire.
1873. *SIEMENS, ALEXANDER, M.Inst.C.E. 12 Queen Anne's-gate, S.W.
1905. ‡Siemens, Mrs. A. 12 Queen Anne's-gate, S.W.
1903. *Silberrad, Dr. Oswald. Buckhurst Hill, Essex.
1871. *SIMPSON, Sir ALEXANDER R., M.D., Emeritus Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1909. §Simpson, Professor J. C. McGill University, Montreal, Canada.
1908. §Simpson, J. J., M.A., B.Sc. Zoological Department, Marischal College, Aberdeen.
1901. *Simpson, Professor J. Y., M.A., D.Sc., F.R.S.E. 25 Chester-street, Edinburgh.
1907. §Simpson, Lieut.-Colonel R. J. S., C.M.G. Care of Messrs. Holt & Co., 3 Whitehall-place, S.W.
1909. *Simpson, Samuel, B.Sc. Wiswell, Whalley, Lancashire.
1909. §Simpson, Sutherland, M.D. Cornell University Medical College, Ithaca, New York, U.S.A.
1894. §Simpson, Thomas, F.R.G.S. Fennymere, Castle Bar, Ealing, W.
1896. *Simpson, W., F.G.S. Catteral Hall, Settle, Yorkshire.
1884. *Simpson, Professor W. J. R., C.M.G., M.D. 31 York-terrace, Regent's Park, N.W.
1909. §Sinclair, J. D. 77 Spence-street, Winnipeg.
1874. ‡SINCLAIR, Right Hon. THOMAS. (Local Sec. 1874.) Dunedin, Belfast.
1907. *Sircar, Dr. Amrita Lal, L.M.S., F.C.S. 51 Sankaritola, Calcutta.
1905. *SJOGREN, Professor H. Natural History Museum, Stockholm, Sweden.
1902. ‡Skeffington, J. B., M.A., LL.D. Waterford.
1906. ‡Skerry, H. A. St. Paul's-square, York.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1898. ‡SKINNER, SIDNEY, M.A. (Local Sec. 1904.) South-Western Polytechnic, Manresa-road, Chelsea, S.W.
1905. *Skyrme, C. G. 28 Norman-road, St. Leonards-on-Sea.
1905. ‡Slater, Dr. H. B. 75 Bree-street, Johannesburg.
1889. §Slater, Matthew B., F.L.S. Malton, Yorkshire.
1887. ‡Small, Evan W., M.A., B.Sc., F.G.S. 48 Kedleston-road, Derby.

Year of Election.

1887. ‡Small, William. Lincoln-circus, The Park, Nottingham.
1903. *Smallman, Raleigh S. Homeside, Devonshire-place, Eastbourne.
1904. ‡Smart, Edward. Benview, Craigie, Perth, N.B.
1889. *Smart, Professor William, LL.D. (Pres. F, 1904.) Nunholme, Dowanhill, Glasgow.
1902. §Smedley, Miss Ida. 11 Mecklenburgh-square, W.C.
1905. ‡Smith, Miss Adelaide. Huguenot College, Wellington, Cape Colony.
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. Chicago, Illinois, U.S.A.
1908 ‡Smith, Alfred. 30 Merrion-square, Dublin.
1897. ‡Smith, Andrew, Principal of the Veterinary College, Toronto, Canada.
1901. *Smith, Miss Annie Lorrain. 20 Talgarth-road, West Kensington, W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, S.W.
1873. ‡Smith, C. Sidney-Sussex College, Cambridge.
1905. ‡Smith, C. H. Fletcher's-chambers, Cape Town.
1889. *Smith, Professor C. Michie, B.Sc., F.R.S.E., F.R.A.S. The Observatory, Kodaikanal, South India.
1900. §Smith, E. J. Grange House, Westgate Hill, Bradford.
1908. ‡Smith, E. Shrapnell. 7 Rosebery-avenue, E.C.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1901. §Smith, F. B. Care of A. Croxton Smith, Esq., Burlington House, Wandle-road, Upper Tooting, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1897. ‡Smith, G. Elliot, M.D., F.R.S. St. John's College, Cambridge.
1903. *Smith, H. B. Lees, M.A. 16 Park-terrace, Oxford.
1889. *Smith, Sir H. Llewellyn, K.C.B., B.A., B.Sc., F.S.S. Board of Trade, S.W.
1860. *Smith, Heywood, M.A., M.D. 40 Portland-court, W.
1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
1902. ‡Smith, J. Lorrain, M.D., Professor of Pathology in the Victoria University, Manchester.
1903. *Smith, James. Pinewood, Crathes, Aberdeen.
1894. §Smith, T. Walrond. Care of Frank Henderson, Esq., 19 Manor-road, Sidcup, Kent.
1896. *Smith, Rev. W. Hodson. Newquay, Cornwall.
1885. *Smith, Watson. 34 Upper Park-road, Haverstock Hill, N.W.
1909. §Smith, William. 218 Sherbrooke-street, Winnipeg, Canada.
1883. ‡Smithells, Arthur, B.Sc., F.R.S. (Pres. B, 1907; Local Sec. 1890), Professor of Chemistry in the University of Leeds.
1906. §Smurthwaite, Thomas E. 134 Mortimer-road, Kensal Rise, N.W.
1905. §Smuts, C. P.O. Box 1088, Johannesburg.
1909. §Smylie, Hugh. 13 Donegall-square North, Belfast.
1908. §Smyly, Sir William J. 58 Merrion-square, Dublin.
1857. *Smyth, John, M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1908 §Smythe, J. A., Ph.D., D.Sc. 15 The Poplars, Gosforth, Newcastle-on-Tyne.
1888. *Snape, H. Lloyd, D.Sc., Ph.D. Balholm, Lathom-road, Southport.
1905. ‡Soddy, F. The University, Glasgow.
1905. ‡Sollas, Miss I. B. J., B.Sc. Newnham College, Cambridge.
1879. *Sollas, W. J., M.A., Sc.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1900; Council, 1900–03), Professor of Geology in the University of Oxford. 173 Woodstock-road, Oxford.
1905. ‡Solomon, R. Stuart. Care of Messrs. R. M. Moss & Co., Cape Town.

Year of Election.

1892. *SOMERVAIL, ALEXANDER. The Museum, Torquay.
1900. *SOMERVILLE, W., D.Sc., F.L.S., Sibthorpian Professor of Rural Economy in the University of Oxford. 121 Banbury-road, Oxford.
1879. *Sorby, Thomas W. Storthfield, Ranmoor, Sheffield.
1901. ‡Sorley, Robert. The Firs, Partickhill, Glasgow.
1903. ‡Soulby, R. M. Sea Holm, Westbourne-road, Birkdale, Lancashire.
1903. ‡Southall, Henry T. The Graig, Ross, Herefordshire.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1909. §Sparling, Rev. J. W., D.D. 159 Kennedy-street, Winnipeg, Canada.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1905. ‡Spencer, Charles Hugh. P.O. Box 2, Maraisburg, Transvaal.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen-park, Highbury, N.
1894. ‡Spiers, A. H. Gresham's School, Holt, Norfolk.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, N.
1864. *Spottiswoode,. W. Hugh, F.C.S. 6 Middle New-street, Fetter-lane, E.C.
1909. §Sprague, D. E. 76 Edmonton-street, Winnipeg, Canada.
1854. *SPRAGUE, THOMAS BOND, M.A., LL.D., F.R.S.E. 29 Buckingham-terrace, Edinburgh.
1905. ‡Squire, Mrs. Clarendon House, 30 St. John's Wood-park, N.W.
1888. *Stacy, J. Sargeant. 164 Shoreditch, E.C.
1903. ‡Stallworthy, Rev. George B. The Manse, Hindhead, Haslemere, Surrey.
1883. *Stanford, Edward, F.R.G.S. 12-14 Long-acre, W.C.
1905. ‡Stanley, Professor George H. Transvaal Technical Institute, Johannesburg.
1883. ‡Stanley, Mrs. Cumberlow, South Norwood, S.E.
1894. *STANSFIELD, ALFRED, D.Sc. McGill University, Montreal, Canada.
1909. §Stansfield, Edgar. McGill University, Toronto, Canada.
1900. *STANSFIELD, H., B.Sc. 19 Cawdor-road, Fallowfield, Manchester.
1905. ‡*Stanwell, H. B. South African College School, Cape Town.*
1905. ‡Stanwell, Dr. St. John. P.O. Box 1050, Johannesburg.
1905. ‡Stapleton, Frederick. Control and Audit Office, Cape Town.
1905. **Starkey, A. H. 24 Greenhead-road, Huddersfield.*
1899. ‡STARLING, E. H., M.D., F.R.S. (Pres. I, 1909), Professor of Physiology in University College, London, W.C.
1898. ‡Stather, J. W., F.G.S. Brookside, Newland Park, Hull.
Staveley, T. K. Ripon, Yorkshire.
1907. §Staynes, Frank. 36-38 Silver-street, Leicester.
1900. *Stead, J. E., F.R.S. Laboratory and Assay Office, Middlesbrough.
1881. ‡Stead, W. H. Beech-road, Reigate.
1892. *STEBBING, Rev. THOMAS R. R., M.A., F.R.S. Ephraim Lodge, The Common, Tunbridge Wells.
1896. *Stebbing, W. P. D., F.G.S. 78A Lexham-gardens, W.
1905. ‡Stebbins, Miss Inez F., B.A. Huguenot College, Wellington, Cape Town.
1908. ‡Steele, Lawrence Edward, M.A., M.R.I.A. 18 Crosthwaite-park East, Kingstown, Co. Dublin.
1909. §Steinkopj, Max. 667 Main-street, Winnipeg, Canada.
1905. ‡Stephen, J. M. Invernegie, Sea Point, Cape Colony.
1884. *Stephens, W. Hudson. Low-Ville, Lewis County, New York, U.S.A.
1902. ‡Stephenson, G. Grianan, Glasnevin, Dublin.

Year of Election.

1910. §STEPHENSON, H. K. (Local Treas. 1910.) Town Hall, Sheffield.
1909. §Stethern, G. A. Fort Frances, Ontario, Canada.
1908. *Steven, Alfred Ingram, M.A., B.Sc. 54 Albert-drive, Pollokshields, Glasgow.
1906. §Stevens, Miss C. O. 11 Woodstock-road, Oxford.
1880. *Stevens, J. Edward, LL.B. Le Mayals, Blackpill, R.S.O.
1900. ‡STEVENS, FREDERICK. (Local Sec. 1900.) Town Clerk's Office, Bradford.
1890. *Steward, Rev. Charles J., F.R.M.S. The Cedars, Anglesea-road, Ipswich.
1885. *Stewart, Rev. Alexander, M.D., LL.D. Murtle, Aberdeen.
1905. §Stewart, A. F. 127 Isabella-street, Toronto, Canada.
1905. ‡Stewart, Charles. Meteorological Commission, Cape Town.
1909. §Stewart, David A., M.D. 407 Pritchard-avenue, Winnipeg, Canada.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Junior Constitutional Club, Piccadilly, W.
1901. *Stewart, John Joseph, M.A., B.Sc. 2 Stow Park-crescent, Newport, Monmouthshire.
1901. *Stewart, Thomas. St. George's-chambers, Cape Town.
1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Victoria University, Manchester.
1904. §Stobbs, J. T. Dunelm, Basford Park, Stoke-on-Trent.
1906. *Stobo, Mrs. Annie. Somerset House, Garelochhead, Dumbartonshire, N.B.
1901. *Stobo, Thomas. Somerset House, Garelochhead, Dumbartonshire, N.B.
1865. *Stock, Joseph S. St. Mildred's, Walmer.
1883. *STOCKER, W. N., M.A. Brasenose College, Oxford.
1898. *Stokes, Professor George J., M.A. 5 Fernhurst-villas, College-road, Cork.
1899. *Stone, Rev. F. J. Radley College, Abingdon.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, E.C.
1905. ‡Stoneman, Miss Bertha, D.Sc. Huguenot College, Wellington, Cape Colony.
1895. *Stoney, Miss Edith A. 30 Chepstow-crescent, W.
1908. *Stoney, Miss Florence A., M.D. 46 Harley-street, W.
1878. *Stoney, G. Gerald. Oakley, Heaton-road, Newcastle-upon-Tyne
1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. (Pres. A, 1897.) 30 Chepstow-crescent, W.
1903. *Stopes, Miss Marie, Ph.D., D.Sc. 53 Stanley-gardens, Haverstock Hill, N.W.
1883. ‡Stopes, Mrs. 53 Stanley-gardens, Haverstock Hill, N.W.
1887. *Storey, H. L. Bailrigg, Lancaster.
1888. *Stothert, Percy K. Woolley Grange, Bradford-on-Avon, Wilts.
1905. *Stott, Clement H., F.G.S. P.O. Box 7, Pietermaritzburg, Natal.
1881. ‡STRAHAN, AUBREY, M.A., F.R.S., F.G.S. (Pres. C, 1904.) Geological Museum, Jermyn-street, S.W.
1905. ‡Strange, Harold F. P.O. Box 2527, Johannesburg.
1881. §STRANGWAYS, C. FOX, F.G.S. Kylemore, Hollycroft-avenue, West Hampstead, N.W.
1908. *Stratton, F. J. M., M.A. Gonville and Caius College, Cambridge.
1906. *Stromeyer, C. E. 9 Mount-street, Albert-square, Manchester.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1898. *Strong, W. M., M.D. 3 Champion-park, Denmark Hill, S.E.
1887. *Stroud, H., M.A., D.Sc., Professor of Physics in the Armstrong College, Newcastle-upon-Tyne.

Year of Election.

1887. *STROUD, WILLIAM, D.Sc., Professor of Physics in the University of Leeds. Care of Messrs. Barr & Stroud, Anniesland, Glasgow.
1905. ‡Struben, Mrs. A. P.O. Box 1228, Pretoria.
1876. *Stuart, Charles Maddock, M.A. St. Dunstan's College, Catford, S.E.
1872. *Stuart, Rev. Canon Edward A., M.A. The Precincts, Canterbury.
1885. ‡Stump, Edward C. Malmesbury, Polefield, Blackley. Manchester.
1909. §Stupart, R. F. Meteorological Service, Toronto, Canada.
1879. *Styring, Robert. Brinkcliffe Tower, Sheffield.
1891. *Sudborough, Professor J. J., Ph.D., D.Sc. University College of Wales, Aberystwyth.
1902. §Sully, H. T. Scottish Widows-buildings, Bristol.
1898. §Sully, T. N. Avalon House, Queen's-road, Weston-super-Mare.
1905. ‡Summer, A. B. Ollersett Booyseux, Transvaal.
1887. *Sumpner, W. E., D.Sc. Technical School, Suffolk-street, Birmingham.
1908. §Sutherland, Alexander. School House, Gersa, Watten, Caithness.
1903. ‡Swallow, Rev. R. D., M.A. Chigwell School, Essex.
1905. ‡Swan, Miss Hilda. Overhill, Warlingham, Surrey.
1881. §SWAN, Sir JOSEPH WILSON, M.A., D.Sc., F.R.S. Overhill, Warlingham, Surrey.
1905. ‡Swan, Miss Mary E. Overhill, Warlingham, Surrey.
1897. ‡Swanston, William, F.G.S. Mount Collyer Factory, Belfast.
1908. ‡Swanzy, Sir Henry R., M.D. 23 Merrion-square, Dublin.
1882. *Swaythling, Lord. 12 Kensington Palace-gardens, W.
1887. ‡SWINBURNE, JAMES, F.R.S., M.Inst.C.E. 82 Victoria-street, S.W.
1870. *Swinburne, Sir John, Bart. Capheaton Hall, Newcastle-upon-Tyne.
1895. ‡Sykes, E. R., B.A. 3 Gray's Inn-place, W.C.
1902. *Sykes, Miss Ella C. Elcombs, Lyndhurst, Hampshire.
1887. *Sykes, George, H., M.A., M.Inst.C.E., F.S.A. Glencoe, 64 Elmbourne-road, Tooting Common, S.W.
1906. *Sykes, Miss M. G. Clarence Cottage, Clare-road, Cambridge.
1896. *Sykes, Mark L., F.R.M.S. 10 Headingley-avenue, Leeds.
1902. *Sykes, Major P. Molesworth, C.M.G. Elcombs, Lyndhurst, Hampshire.
1906. ‡Sykes, T. P., M.A. 4 Gathorne-street, Great Horton, Bradford.
1905. ‡Symington, C., M.B. Railway Medical Office, De Aar, Cape Colony.
1903. §Symington, Howard W. Brooklands, Market Harborough.
1885. ‡SYMINGTON, JOHNSON, M.D., F.R.S., F.R.S.E. (Pres. H, 1903), Professor of Anatomy in Queen's College, Belfast.
1905. ‡Symmes, H. C. P.O. Box 3902, Johannesburg.
1908. ‡Synnott, Nicholas J. Furness, Naas, Co. Kildare.

1896. ‡Tabor, J. M. Holmwood, Haringey Park, Crouch End, N.
1904. §Tallack, H. T. Clovelly, Birdhurst-road, South Croydon.
1903. *Tanner, Miss Ellen G. Parkside, Corsham, Wilts.
1890. ‡TANNER, H. W. LLOYD, D.Sc., F.R.S. (Local Sec. 1891), Professor of Mathematics and Astronomy in University College, Cardiff.
1892. *Tansley, Arthur G., M.A., F.L.S. Grantchester, near Cambridge.
1883. *Tapscott, R. Lethbridge, F.R.A.S. 62 Croxteth-road, Liverpool.
1908. ‡TARLETON, FRANCIS A., LL.D. 24 Upper Leeson-street, Dublin.
1861. *Tarratt, Henry W. 2c Oxford and Cambridge-mansions, Hyde Park, W.

Year of Election.

1902. ‡Tate, Miss. Rantalard, Whitehouse, Belfast.
1901. ‡*Taylor, Benson.* 22 *Hayburn-crescent, Partick, Glasgow.*
1908. ‡Taylor, Rev. Campbell, M.A. United Free Manse, Wigtown, Scotland.
1887. ‡Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1898. ‡Taylor, Lieut.-Colonel G. L. Le M. 6 College-lawn, Cheltenham.
1881. *Taylor, H. A. 12 Melbury-road, Kensington, W.
1906. ‡Taylor, H. Dennis. Stancliffe, Mount-villas, York.
1884. *TAYLOR, H. M., M.A., F.R.S. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. Oxford-street, Nottingham.
1860. *Taylor, John, M.Inst.C.E. 6 Queen Street-place, E.C.
1906. §Taylor, Miss M. R. Newstead, Blundellsands.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1895. ‡Taylor, W. A., M.A., F.R.S.E. 3 East Mayfield, Edinburgh.
1894. *Taylor, W. W., M.A. 66 St. John's-road, Oxford.
1903. ‡Taylor, William. 61 Cambridge-road, Southport.
1901. *Teacher, John H., M.B. 32 Kingsborough-gardens, Glasgow.
1858. ‡TEALE, THOMAS PRIDGIN, M.A., F.R.S. 38 Cookridge-street, Leeds.
1885. ‡TEALL, J. J. H., M.A., F.R.S., F.G.S. (Pres. C, 1893; Council, 1894–1900, 1909–), Director of the Geological Survey of the United Kingdom. The Museum, Jermyn-street, S.W.
1906. *Teape, Rev. W. M., M.A. South Hylton Vicarage, Sunderland.
1879. ‡Temple, Lieutenant G. T., R.N., F.R.G.S. Solheim, Cumberland Park, Acton, W.
1896. *Terry, Rev. T. R., M.A., F.R.A.S. The Rectory, East Ilsley, Newbury, Berkshire.
1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1882. *THANE, GEORGE DANCER, LL.D., Professor of Anatomy in University College, London, W.C.
1871. ‡THISELTON-DYER, Sir W. T., K.C.M.G., C.I.E., M.A., B.Sc., Ph.D., LL.D., F.R.S., F.L.S. (Pres. D, 1888; Pres. K, 1895; Council, 1885–89, 1895–1900.) The Ferns, Witcombe, Gloucester.
1906. *Thoday, D. Trinity College, Cambridge.
1870. ‡Thom, Colonel Robert Wilson, J.P. Brooklands, Lord-street West, Southport.
1891. *Thomas, Miss Clara. Pencerrig, Builth.
1903. *THOMAS, Miss ETHEL N., B.Sc. 3 Downe-mansions, Gondar-gardens, West Hampstead, N.W.
1880. *Thomas, Joseph William, F.C.S. Overdale, Shortlands, Kent.
1899. *Thomas, Mrs. J. W. Overdale, Shortlands, Kent.
1902. *Thomas, Miss M. Beatrice. Girton College, Cambridge.
1883. ‡Thomas, Thomas H. 45 The Walk, Cardiff.
1904. *Thomas, William. Bryn-heulog, Merthyr Tydfil.
1891. *Thompson, Beeby, F.C.S., F.G.S. 67 Victoria-road, Northampton.
1888. *Thompson, Claude M., M.A., D.Sc., Professor of Chemistry in University College, Cardiff. 38 Park-place, Cardiff.
1885. ‡THOMPSON, D'ARCY W., B.A., C.B., Professor of Zoology in University College, Dundee.
1896. *Thompson, Edward P. Paulsmoss, Whitchurch, Salop.
1907. *Thompson, Edwin. 1 Croxteth-grove, Liverpool.
1883. *Thompson, Francis. Eversley, Haling Park-road, Croydon.
1904. *Thompson, G. R., B.Sc., Professor of Mining in the University of Leeds.

Year of Election.

1893. *Thompson, Harry J., M.Inst.C.E., Madras. Care of National Bank of India, 17 Bishopsgate-street Within, E.C.
1883. *Thompson, Henry G., M.D. 86 Lower Addiscombe-road, Croydon.
1905. ‡Thompson, James. P.O. Box 312, Johannesburg.
1909. §Thompson, Miss Mabel. Ashbourne Cottage, Blanford-road, Reigate.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1876. ‡Thompson, Silvanus Phillips, B.A., D.Sc., F.R.S., F.R.A.S. (Pres. G, 1907; Council, 1897–99), Principal and Professor of Physics in the City and Guilds of London Technical College, Leonard-street, Finsbury, E.C.
1883. *Thompson, T. H. Oldfield Lodge, Gray-road, Bowdon, Cheshire.
1896. *Thompson, W. H., M.D., D.Sc. (Local Sec. 1908), King's Professor of Institutes of Medicine (Physiology) in Trinity College, Dublin. 14 Hatch-street, Dublin.
1905. ‡*Thompson, William. Parkside, Doncaster-road, Rotherham.*
1894. ‡Thomson, Arthur, M.A., M.D., Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.
1909. *Thomson, E. 22 Monument-avenue, Swampscott, Mass., U.S.A.
1906. §Thomson, F. Ross, F.G.S. Hensill, Hawkhurst, Kent.
1890. *Thomson, Professor J. Arthur, M.A., F.R.S.E. Castleton House, Old Aberdeen.
1883. ‡Thomson, Sir J. J., M.A., Sc.D., D.Sc., F.R.S. (President; Pres. A, 1896; Council, 1893–95), Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1901. ‡Thomson, Dr. J. T. Kilpatrick. 148 Norfolk-street, Glasgow.
1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1891. ‡Thomson, John. Westover, Mount Ephraim-road, Streatham, S.W.
1871. *Thomson, John Millar, LL.D., F.R.S. (Council, 1895–1901), Professor of Chemistry in King's College, London. 9 Campden Hill-gardens, W.
1874. ‡Thomson, William, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1906. ‡Thornely, Miss A. M. M. Oaklands, Langham-road, Bowdon, Cheshire.
1905. *Thornely, Miss L. R. Nunclose, Grassendale, Liverpool.
1898. *Thornton, W. M., D.Sc., Professor of Electrical Engineering in the Armstrong College, Newcastle-on-Tyne.
1902. ‡Thornycroft, Sir John I., F.R.S., M.Inst.C.E. Eyot Villa, Chiswick Mall, W.
1903. ‡Thorp, Edward. 87 Southbank-road, Southport.
1881. ‡Thorp, Fielden. Blossom-street, York.
1881. *Thorp, Josiah. 37 Pleasant-street, New Brighton, Cheshire.
1898. §Thorp, Thomas. Moss Bank, Whitefield, Manchester.
1898. ‡Thorpe, Jocelyn Field, Ph.D., F.R.S. Victoria University, Manchester.
1871. ‡Thorpe, Sir T. E., C.B., Ph.D., LL.D., F.R.S., F.R.S.E., V.P.C.S. (Pres. B, 1890; Council, 1886–92.) 61 Ladbroke-grove, W.
1899. §Threlfall, Richard, M.A., F.R.S. 30 George-road, Edgbaston, Birmingham.
1896. §Thrift, William Edward, M.A. (Local Sec. 1908), Professor of Natural and Experimental Philosophy in the University of Dublin. 80 Grosvenor-square, Rathmines, Dublin.

Year of Election.

1904. §Thurston, Edgar, C.I.E. Government Museum, Madras.
1907. §Thwaites, R. E. 28 West-street, Leicester.
1889. ‡Thys, Colonel Albert. 9 Rue Briderode, Brussels.
1873. *TIDDEMAN, R. H., M.A., F.G.S. 298 Woodstock-road, Oxford.
1905. ‡Tietz, Heinrich, B.A., Ph.D. South African College, Cape Town.
1874. ‡TILDEN, Sir WILLIAM A., D.Sc., F.R.S., F.C.S. (Pres. B, 1888; Council, 1898–1904), Professor of Chemistry in the Imperial College of Science, London. The Oaks, Northwood, Middlesex.
1896. §Timmis, Thomas Sutton. Cleveley, Allerton, Liverpool.
1899. ‡Tims, H. W. Marett, M.A., M.D., F.L.S. Deepdene, Cavendish-avenue, Cambridge.
1902. ‡Tipper, Charles J. R., B.Sc. 21 Greenside, Kendal.
1905. ‡Tippett, A. M., M.Inst.C.E. Cape Government Railways, Cape Town.
1900. §Tocher, J. F., B.Sc., F.I.C. 5 Chapel-street, Peterhead, N.B.
1907. §Todd, Professor J. L. MacDonald College, Quebec, Canada.
1889. §Toll, John M. 49 Newsham-drive, Liverpool.
1905. ‡Tonkin, Samuel. Rosebank, near Cape Town.
1875. ‡Torr, Charles Hawley. 35 Burlington-road, Sherwood, Nottingham.
1909. §Tory, H. M. Edmonton, Alberta, Canada.
1901. ‡Townsend, J. S. E., M.A., F.R.S., Professor of Physics in the University of Oxford. New College, Oxford.
1876. *TRAIL, J. W. H., M.A., M.D., F.R.S., F.L.S., Regius Professor of Botany in the University of Aberdeen.
1883. ‡TRAILL, A., M.D., LL.D., Provost of Trinity College, Dublin, Ballylough, Bushmills, Ireland.
1870. ‡TRAILL, WILLIAM A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1868. ‡TRAQUAIR, RAMSAY H., M.D., LL.D., F.R.S., F.G.S. (Pres. D, 1900.) The Bush, Colinton, Midlothian.
1902. ‡Travers, Ernest J. Dunmurry, Co. Antrim.
1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
1908. §Treen, Henry M. Wicken, Sohan, Cambridge.
1908. ‡Tremain, Miss Caroline P., B.A. Alexandra College, Dublin.
1887. *Trench-Gascoigne, Mrs. F. R. Lotherton Hall, Parlington, Aberford, Leeds.
1903. ‡Trenchard, Hugh. The Firs, Clay Hill, Enfield.
1908. ‡Tresilian, R. S. Cumnor, Eglington-road, Dublin.
1905. ‡TREVOR-BATTYE, A., M.A., F.L.S., F.R.G.S. Chilbolton, Stockbridge, R.S.O.
1871. ‡TRIMEN, ROLAND, M.A., F.R.S., F.L.S., F.Z.S. Ovingdean, King Charles-road, Surbiton Hill.
1902. ‡Tristram, Rev. J. F., M.A., B.Sc. 20 Chandos-road, Chorlton-cum-Hardy, Manchester.
1884. *Trotter, Alexander Pelham. 8 Richmond-terrace, Whitehall, S.W.
1887. *TROUTON, FREDERICK T., M.A., Sc.D., F.R.S., Professor of Physics in University College, W.C.
1898. §Trow, Albert Howard, D.Sc., F.L.S., Professor of Botany in University College, Cardiff. 50 Clive-road, Penarth.
1885. *Tubby, A. H., F.R.C.S. 68 Harley-street, W.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1905. §Turmeau, Charles. Claremont, Victoria Park, Wavertree, Liverpool.
1901. §Turnbull, Robert, B.Sc. Department of Agriculture and Technical Instruction, Dublin.
1893. ‡TURNER, DAWSON, M.B. 37 George-square, Edinburgh.

Year of Election

1894. *Turner, H. H., M.A., D.Sc., F.R.S., F.R.A.S., Professor of Astronomy in the University of Oxford. The Observatory, Oxford.
1905. ‡Turner, Rev. Thomas. St. Saviour's Vicarage, 50 Fitzroy-street, W.
1886. *Turner, Thomas, M.Sc., A.R.S.M., F.I.C., Professor of Metallurgy in the University of Birmingham. Springfields, Upland-road, Selly Hill, Birmingham.
1863. *Turner, Sir William, K.C.B., LL.D., D.C.L., F.R.S., F.R.S.E. (President, 1900; Pres. H, 1889, 1897), Principal of the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1910. §Turner, W. E. S. The University, Sheffield.
1890. *Turpin, G. S., M.A., D.Sc. High School, Nottingham.
1907. §Tutton, A. E. H., M.A., D.Sc., F.R.S. (Council, 1908– .) 41 Ladbroke-square, W.
1886. *Twigg, G. H. 6 & 7 Ludgate-hill, Birmingham.
1899. ‡Twisden, John R., M.A. 14 Gray's Inn-square, W.C.
1907. §Twyman, F. 75a Camden-road, N.W.
1865. ‡Tylor, Edward Burnett, D.C.L., LL.D., F.R.S. (Pres. H, 1884; Council, 1896–1902), Professor of Anthropology in the University of Oxford. Museum House, Oxford.
1883. ‡Tyrer, Thomas, F.C.S. Stirling Chemical Works, Abbey-lane, Stratford, E.

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1903. ‡Underwood, Captain J. C. 60 Scarisbrick New-road, Southport.
1908. §Unwin, Ernest Ewart, M.Sc. Bootham School, York.
1885. §Unwin, Howard. 1 Newton-grove, Bedford Park, Chiswick, W.
1883. §Unwin, John. Eastcliffe Lodge, Southport.
1876. *Unwin, W. C., F.R.S., M.Inst.C.E. (Pres. G, 1892; Council, 1892–99.) 7 Palace Gate-mansions, Kensington, W.
1909. §Urquhart, C. 239 Smith-street, Winnipeg, Canada.
1902. §Ussher, R. J. Cappagh House, Cappagh, Co. Waterford.
1880. ‡Ussher, W. A. E., F.G.S. 28 Jermyn-street, S.W.
1905. ‡Uttley, E. A., Electrical Inspector to the Rhodesian Government, Bulawayo.

1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1908. ‡Valera, Edward de. University College, Blackrock, Dublin.
1905. ‡Van der Byl, J. A. P.O., Irene, Transvaal.
1883. *Vansittart, The Hon. Mrs. A. A. Haywood House, Oaklands-road, Bromley, Kent.
1865. *Varley, S. Alfred. Arrow Works, Jackson-road, Holloway, N.
1907. §Varley, W. Mansergh, M.A., D.Sc., Ph.D. 27 St. Hilary-terrace, Devonport.
1903. ‡Varwell, H. B. 2 Pennsylvania-park, Exeter.
1909. *Vassall, H., M.A. The Priory, Repton, Burton-on-Trent.
1907. §Vaughan, Arthur, B.A., D.Sc., F.G.S. 9 Pembroke-vale, Clifton, Bristol.
1895. ‡Vaughan, D. T. Gwynne, F.L.S. Queen's College, Belfast.
1905. ‡Vaughan, E. L. Eton College, Windsor.
1881. ‡Veley, V. H., M.A., D.Sc., F.R.S. 8 Marlborough-place, St. John's Wood, N.W.
1873. *Verney, Sir Edmund H., Bart., F.R.G.S. Claydon House, Winslow, Bucks.
1883. *Verney, Lady. Claydon House, Winslow, Bucks.

Year of Election.

1904. *Vernon, H. M., M.A., M.D. 22 Norham-road, Oxford.
1896. *Vernon, Thomas T. Shotwick Park, Chester.
1896. *Vernon, William. Shotwick Park, Chester.
1890. *Villamil, Lieut.-Colonel R. de, R.E. Carlisle Lodge, Rickmansworth.
1906. *VINCENT, J. H., M.A., D.Sc. L.C.C. Paddington Technical Institute, Saltram-crescent, W.
1899. *VINCENT, SWALE, M.D., D.Sc. (Local Sec. 1909), Professor of Physiology in the University of Manitoba, Winnipeg, Canada.
1883. *VINES, SYDNEY HOWARD, M.A., D.Sc., F.R.S., F.L.S. (Pres. K, 1900; Council, 1894–97), Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1902. §Vinycomb, T. B. Sinn Fein, Shooter's Hill, S.E.
1904. §Volterra, Professor Vito. Regia Universita, Rome.

1904. §Wace, A. J. B. Pembroke College, Cambridge.
1902. ‡Waddell, Rev. C. H. The Vicarage, Saintfield.
1909. §Wadge, Herbert W., M.D. 754 Logan-avenue, Winnipeg, Canada.
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.
1890. §WAGER, HAROLD W. T., F.R.S., F.L.S. (Pres. K, 1905.) Hendre, Horsforth-lane, Far Headingley, Leeds.
1900. ‡Wagstaff, C. J. L., B.A. Grafton House, Oundle.
1902. ‡Wainwright, Joel. Finchwood, Marple Bridge, Stockport.
1906. ‡Wakefield, Charles. Heslington House, York.
1905. §Wakefield, Captain E. W. Stricklandgate House, Kendal.
1894. ‡WALFORD, EDWIN A., F.G.S. 21 West Bar, Banbury.
1882. *Walkden, Samuel, F.R.Met.S. The Cottage, Whitchurch, Tavistock.
1893. ‡Walker, Alfred O., F.L.S. Ulcombe-place, Maidstone, Kent.
1890. ‡Walker, A. Tannett. The Elms, Weetwood, Leeds.
1901. *Walker, Archibald, M.A., F.I.C. 7 Crown-terrace, Glasgow.
1897. *WALKER, B. E., D.C.L., F.G.S. (Local Sec. 1897.) Canadian Bank of Commerce, Toronto, Canada.
1904. §Walker, E. R. Nightingales, Adlington, Lancashire.
1891. ‡Walker, Frederick W. Tannett. Carr Manor, Meanwood, Leeds.
1905. ‡Walker, G. M. Lloyd's-buildings, Burg-street, Cape Town.
1894. *WALKER, G. T., M.A., D.Sc., F.R.S., F.R.A.S. Red Roof, Simla, India.
1897. ‡Walker, George Blake. Tankersley Grange, near Barnsley.
1906. ‡Walker, J. F. E. Gelson, B.A. 45 Bootham, York.
1894. *WALKER, JAMES, M.A. 30 Norham-gardens, Oxford.
1906. §Walker, Dr. Jamieson. 37 Charnwood-street, Derby.
1909. §Walker, Louis D. 319 Edmonton-street, Winnipeg, Canada.
1907. ‡Walker, Philip F., F.R.G.S. 36 Prince's-gardens, S.W.
1908. *Walker, Robert. Westray, Combe Down, Bath.
1888. ‡Walker, Sydney F. 1 Bloomfield-crescent, Bath.
1896. §Walker, Colonel William Hall, M.P. Gateacre, Liverpool.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1863. ‡WALLACE, ALFRED RUSSEL, O.M., D.C.L., F.R.S., F.L.S., F.R.G.S. (Pres. D. 1876; Council, 1870–72.) Broadstone, Wimborne, Dorset.
1905. ‡Wallace, R. W. 2 Harcourt-buildings, Temple, E.C.
1901. ‡Wallace, William, M.A., M.D. 25 Newton-place, Glasgow.
1887. *WALLER, AUGUSTUS D., M.D., F.R.S. (Pres. I, 1907.) 32 Grove End-road, N.W.
1905. §Waller, Mrs. 32 Grove End-road, N.W.
1889. *Wallis, Arnold J., M.A., 5 Belvoir-terrace, Cambridge.

Year of Election.

1895. ‡WALLIS, E. WHITE, F.S.S. Royal Sanitary Institute and Parkes Museum, 90 Buckingham Palace-road, S.W.
1894. *WALMISLEY, A. T., M.Inst.C.E. 9 Victoria-street, Westminster, S.W.
1891. §Walmsley, R. M., D.Sc. Northampton Institute, Clerkenwell, E.C.
1908. ‡Walsh, John M. Pleona Park-avenue, Sidney-parade, Dublin.
1903. ‡Walsh, W. T. H. Toynbee Hall, Whitechapel, E.
1895. ‡WALSINGHAM, The Right Hon. Lord, LL.D., F.R.S. Merton Hall, Thetford.
1902. *Walter, Miss L. Edna. 38 Woodberry-grove, Finsbury Park, N.
1904. *Walters, William, jun. Etheldreda House, Exning, Newmarket.
1887. ‡WARD, A. W., M.A., Litt.D., Master of Peterhouse, Cambridge.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1874. ‡Ward, John, J.P., F.S.A. Beesfield, Farningham, Kent.
1905. ‡Warlow, Dr. G. P. 15 Hamilton-square, Birkenhead.
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1896. ‡Warrand, Major-General, R.E. Westhorpe, Southwell.
1887. ‡WARREN, Lieut.-General Sir CHARLES, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. (Pres. E, 1887.) Athenæum Club, S.W.
1875. *WATERHOUSE, Major-General J. Hurstmead, Eltham, Kent.
1905. ‡Watermeyer, F. S., Government Land Surveyor. P.O. Box 973, Pretoria, South Africa.
1904. ‡Waters, A. H., B.A. 48 Devonshire-road, Cambridge.
1900. ‡Waterston, David, M.D., F.R.S.E. 23 Colinton-road, Edinburgh.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. 2 Countess-road, Nuneaton.
1909. §Watkinson, Professor W. H. The University, Liverpool.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1901. *WATSON, ARNOLD THOMAS, F.L.S. Southwold, Tapton Crescent-road, Sheffield.
1886. *Watson, C. J. Alton Cottage, Botteville-road, Acock's Green, Birmingham.
1909. §Watson, Colonel Sir C. M., K.C.M.G., C.B., R.E., M.A. 16 Wilton-crescent, S.W.
1906. §Watson, D. M. S. Windlehurst, Anson-road, Victoria Park, Manchester.
1909. §Watson, Ernest Ansley, B.Sc. Alton Cottage, Botteville-road, Acock's Green, Birmingham.
1892. ‡Watson, G., M.Inst.C.E. Moorlands, Worcester.
1885. ‡Watson, Deputy Surgeon-General G.A. Hendre, Overton Park, Cheltenham.
1906. *Watson, Henry Angus. 3 Museum-street, York.
1889. ‡Watson, John, F.I.C. P.O. Box 1026, Johannesburg, South Africa.
1905. ‡Watson, Dr. R. W. Ladysmith, Cape Colony.
1894. *WATSON, Professor W., D.Sc., F.R.S. 7 Upper Cheyne-row, S.W.
1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. Braystones House, Beckermet, Cumberland.
1901. §Watt, Harry Anderson, M.P. Ardenslate House, Hunter's Quay, Argyllshire.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1884. *Watts, Rev. Canon Robert R. The Red House, Bemerton, Salisbury.
1873. *WATTS, W. MARSHALL, D.Sc. Shirley, Venner-road, Sydenham, S.E.

Year of
Election.

1883. *WATTS, W. W., M.A., M.Sc., F.R.S., F.G.S. (Pres. C, 1903; Council, 1902-09), Professor of Geology in the Imperial College of Science, London, S.W.
1870. §Watts, William, F.G.S. Kenmore, Wilmslow, Cheshire.
1905. ‡Way, E. J. Post Office, Benoni, Transvaal.
1905. ‡Way, W. A., M.A. The College, Graaf Reinet, South Africa.
1905. ‡Webb, Miss Dora. Gezina School, Pretoria.
1907. ‡Webb, Wilfred Mark. Odstock, Hanwell, W.
1891. ‡Webber, Thomas. 12 Southey-terrace, Wordsworth-avenue, Roath, Cardiff.
1909. §Webster, William, M.D. 1252 Portage-avenue, Winnipeg, Canada.
1908. §Wedderburn, Ernest Maclagan, F.R.S.E. 6 Luccoth-gardens, Edinburgh.
1903. ‡Weekes, R. W., A.M.Inst.C.E. 65 Hayes-road, Bromley, Kent.
1890. *WEISS, F. ERNEST, D.Sc., F.L.S., Professor of Botany in the Victoria University, Manchester.
1905. ‡Welby, Miss F. A. Hamilton House, Hall-road, N.W.
1902. ‡Welch, R. J. 49 Lonsdale-street, Belfast.
1894. ‡Weld, Miss. 119 Iffley-road, Oxford.
1880. *Weldon, Mrs. Merton Lea, Oxford.
1908. ‡Welland, Rev. C. N. Wood Park, Kingstown, Co. Dublin.
1881. §Wellcome, Henry S. Snow Hill-buildings, E.C.
1908. ‡Wellisch, E. M. 17 Park-street, Cambridge.
1881. ‡Wells, Rev. Edward, M.A. West Dean Rectory, Salisbury.
1881. *WENLOCK, The Right Hon. Lord, G.C.S.I., G.C.I.E., K.C.B., LL.D. Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Roslyn, Walland's Park, Lewes.
1886. *Wertheimer, Julius, B.A., B.Sc., F.C.S., Principal of and Professor of Chemistry in the Merchant Venturers' Technical College, Bristol.
1900. §WEST, WILLIAM, F.L.S. 26 Woodville-terrace, Horton-lane, Bradford.
1903. §Westaway, F. W. 1 Pemberley-crescent, Bedford.
1882. *Westlake, Ernest, F.G.S. Fordingbridge, Salisbury.
1900. ‡Wethey, E. R., M.A., F.R.G.S. 4 Cunliffe-villas, Manningham, Bradford.
1909. §Wheeler, A. O., F.R.G.S. P.O. Box 167, Calgary, Alberta, Canada.
1878. *Wheeler, W. H., M.Inst.C.E. 4 Hope-park, Bromley, Kent.
1888. §Whelen, John Leman. 23 Fairhazel-gardens, N.W.
1893. *WHETHAM, W. C. D., M.A., F.R.S. Upwater Lodge, Cambridge.
1888. *Whidborne, Miss Alice Maria. Charanté, Torquay.
1879. *WHIDBORNE, Rev. GEORGE FERRIS, M.A., F.G.S. Hammerwood Lodge, East Grinstead, Sussex.
1898. *Whipple, Robert S. Scientific Instrument Company, Cambridge.
1883. *Whitaker, T. Walton House, Burley-in-Wharfedale.
1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. (Pres. C, 1895; Council, 1890–96.) 3 Campden-road, Croydon.
1884. ‡Whitcher, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1886. ‡Whitcombe, E. B. Borough Asylum, Winson Green, Birmingham.
1897. ‡Whitcombe, George. The Wotton Elms, Wotton, Gloucester.
1886. ‡WHITE, A. SILVA. Clarendon Lodge, St. John's-gardens, Holland Park, N.
1908. ‡White, Mrs. A. Silva. Clarendon Lodge, St. John's-gardens, Holland Park, N.

Year of Election.

1904. ‡White, H. Lawrence, B.A. 2 St. Margaret's-terrace, Cheltenham.
1885. *White, J. Martin. Balruddery, Dundee.
1905. ‡White, Miss J. R. Huguenot College, Wellington, Cape Colony.
1897. *White, Sir W. H., K.C.B., F.R.S. (Pres. G, 1899, 1909; Council, 1897–1900.) Cedarcroft, Putney Heath, S.W.
1877. *White, William. 20 Hillersdon-avenue, Church-road, Barnes, S.W.
1904. ‡Whitehead, J. E. L., M.A. (Local Sec. 1904). Guildhall, Cambridge.
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1905. §Whiteley, Miss M. A., D.Sc. Imperial College of Science, S.W.
1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. Municipal Science and Technical School, West Bromwich.
1907. *Whitley, E. Clovelly, Sefton Park, Liverpool.
1905. *Whitmee, H. B. P.O. Box 470, Durban, Natal.
1891. ‡Whitmell, Charles T., M.A., B.Sc. Invermay, Hyde Park, Leeds.
1897. ‡Whittaker, E. T., M.A., F.R.S., Royal Astronomer of Ireland and Andrews' Professor of Astronomy in the University of Dublin. The Observatory, Dunsink, Co. Dublin.
1901. ‡Whitton, James. City-chambers, Glasgow.
1857. *Whitty, Rev. John Irwine, M.A., D.C.L., LL.D. Alpha Villa, Southwood, Ramsgate.
1905. ‡Whyte, B. M. Simon's Town, Cape Colony.
1905. §Wibberley, C. Beira and Mashonaland Railways, Umtali, South Africa.
1881. **Wigglesworth, Robert. Ashtead Lodge, Surrey.*
1889. *Wilberforce, L. R., M.A., Professor of Physics in the University of Liverpool.
1887. *Wilde, Henry, D.Sc., D.C.L., F.R.S. The Hurst, Alderley Edge, Cheshire.
1905. ‡Wiley, J. R. Kingsfold, Mill-street, Cape Town.
1905. ‡Wilkins, R. F. Thatched House Club, St. James's-street, S.W.
1904. §Wilkinson, Hon. Mrs. Dringhouses Manor, York.
1900. §Wilkinson, J. B. Holme-lane, Dudley Hill, Bradford.
1903. ‡Willett, John E. 3 Park-road, Southport.
1904. *Williams, Miss Antonia. 6 Sloane-gardens, S.W.
1861. *Williams, Charles Theodore, M.V.O., M.A., M.D. 2 Upper Brook-street, Grosvenor-square, W.
1905. §Williams, Gardner F. 2201 R-street, Washington, D.C., U.S.A.
1883. ‡Williams, Rev. H. Alban, M.A. Sheering Rectory, Harlow, Essex.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1891. §Williams, J. A. B., M.Inst.C.E. The Hurst, Branksome Park, Bournemouth.
1883. *Williams, Mrs. J. Davies. 5 Chepstow-mansions, Bayswater, W.
1888. *Williams, Miss Katharine T. Llandaff House, Pembroke-vale, Clifton, Bristol.
1901. *Williams, Miss Mary. 6 Sloane-gardens, S.W.
1891. ‡Williams, Morgan. 5 Park-place, Cardiff.
1883. ‡Williams, T. H. 27 Water-street, Liverpool.
1877. *Williams, W. Carleton, F.C.S. Broomgrove, Goring-on-Thames.
1906. ‡Williams, W. F. Lobb. 32 Lowndes-street, S.W.
1857. ‡Williamson, Benjamin, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1894. **Williamson, Mrs. Janora. Ardoyne, Birkbeck-road, Muswell Hill, N.*
1895. ‡Willink, W. (Local Sec. 1896.) 14 Castle-street, Liverpool.

Year of
Election.

1895. ‡Willis, John C., M.A., F.L.S., Director of the Royal Botanical Gardens, Peradeniya, Ceylon.
1896. ‡WILLISON, J. S. (Local Sec. 1897.) Toronto, Canada.
1859. *Wills, The Hon. Sir Alfred. Saxholm, Basset, Southampton.
1899. §Willson, George. Ivanhoe, Combermere-road, St. Leonards-on-Sea.
1899. §Willson, Mrs. George. Ivanhoe, Combermere-road, St. Leonards-on-Sea.
1908. §Wilson, Miss. Grove House, Paddock, Huddersfield.
1901. ‡Wilson, A. Belvoir Park, Newtownbreda, Co. Down.
1886. ‡*Wilson, Alexander B. Holywood, Belfast.*
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. United Free Church Manse, North Queensferry.
1905. §Wilson, A. W. P.O. Box 24, Langlaagte, South Africa.
1907. §Wilson, A. W. 20 Westcott-street, Hull.
1903. ‡Wilson, C. T. R., M.A., F.R.S. Sidney Sussex College, Cambridge.
1894. *Wilson, Charles J., F.I.C., F.C.S. 14 Old Queen-street, Westminster, S.W.
1904. §Wilson, Charles John, F.R.G.S. Deanfield, Hawick, Scotland.
1904. §Wilson, David, M.D. Grove House, Paddock, Huddersfield.
1900. *Wilson, Duncan R. 109A Whitehall-court, S.W.
1903. ‡Wilson, George. The University, Leeds.
1895. ‡Wilson, Dr. Gregg. Queen's College, Belfast.
1901. ‡Wilson, Harold A., M.A., D.Sc., F.R.S., Professor of Physics in King's College, London. 3 & 4 Clement's Inn, Strand, W.C.
1902. *Wilson, Harry, F.I.C. 32 Westwood-road, Southampton.
1879. ‡Wilson, Henry J. 255 Pitsmore-road, Sheffield.
1908. §Wilson, Professor James, M.A., B.Sc. Cluny, Orwell Park, Dublin.
1865. ‡WILSON, Ven. Archdeacon JAMES M., M.A., F.G.S. The Vicarage, Rochdale.
1884. ‡Wilson, James S. Grant. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1901. *Wilson, Joseph. Hillside, Avon-road, Walthamstow, N.E.
1908. *Wilson, Malcolm, B.Sc. Royal College of Science, S.W.
1909. §Wilson, R. A. Hinton, Londonderry.
1903. ‡Wilson, Dr. R. Arderne. Saasveld House, Kloof-street, Cape Town.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1892. ‡Wilson, T. Stacey, M.D. 27 Wheeley's-road, Edgbaston, Birmingham.
1887. §Wilson, W., jun. Battlehillock, Kildrummy, Mossat, Aberdeenshire.
1909. §Wilson, W. Murray. 29 South Drive, Harrogate.
1907. §Wimperis, H. E. 28 Rossetti Garden-mansions, S.W.
1886. ‡WINDLE, BERTRAM C. A., M.A., M.D., D.Sc., F.R.S., President of Queen's College, Cork.
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. (Local Sec. 1864.) 11 Cavendish-crescent, Bath.
1905. §Wiseman, J. G., F.R.C.S., F.R.G.S. Stranraer, St. Peter's-road, St. Margaret's-on-Thames.
1875. ‡WOLFE-BARRY, Sir JOHN, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1898; Council, 1899–1903, 1909– .) Dartmouth House, 2 Queen Anne's-gate, Westminster, S.W.
1905. ‡Wood, A., jun. Emmanuel College, Cambridge.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1875. *Wood, George William Rayner. Singleton Lodge, Manchester.
1908. §Wood, Henry J. 4 Elsworthy-road, N.W.

Year of Election.

1878. ‡Wood, Sir H. Trueman, M.A. Royal Society of Arts, John-street, Adelphi, W.C.; and Prince Edward's-mansions, Bayswater, W.
1883. *Wood, J. H. 21 Westbourne-road, Birkdale, Lancashire.
1904. *Wood, T. B., M.A., Professor of Agriculture in the University of Cambridge. Caius College, Cambridge.
1899. *Wood, W. Hoffman. Ben Rhydding, Yorkshire.
1901. *Wood, William James, F.S.A.(Scot.) 266 George-street, Glasgow.
1899. *Woodcock, Mrs. E. M. Care of Messrs. Stilwell & Harley, 4 St. James'-street, Dover.
1896. *Woodhead, Professor G. Sims, M.D. Pathological Laboratory, Cambridge.
1888. *Woodiwiss, Mrs. Alfred. 121 Castlenau, Barnes, S.W.
1906. ‡Woodland, W. N. F. University College, Gower-street, W.C.
1904. §Woodrow, John. Berryknowe, Meikleriggs, Paisley.
1904. ‡Woods, Henry, M.A. St. John's College, Cambridge.
Woods, Samuel. 1 Drapers'-gardens, Throgmorton-street, E.C.
1887. *Woodward, Arthur Smith, LL.D., F.R.S., F.L.S., F.G.S. (Pres. C, 1909; Council, 1903–), Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
1869. *Woodward, C. J., B.Sc., F.G.S. The Lindens, St. Mary's-road, Harborne, Birmingham.
1886. ‡Woodward, Harry Page, F.G.S. 129 Beaufort-street, S.W.
1866. ‡Woodward, Henry, LL.D., F.R.S., F.G.S. (Pres. C, 1887; Council, 1887–94.) 13 Arundel-gardens, Notting Hill, W.
1870. ‡Woodward, Horace B., F.R.S., F.G.S. Geological Survey Office, Jermyn-street, S.W.
1894. *Woodward, John Harold. 8 Queen Anne's-gate, Westminster, S.W.
1909. *Woodward, Robert S. Carnegie Institution, Washington, U.S.A.
1908. §Woolacott, David, D.Sc., F.G.S. 8 The Oaks West, Sunderland.
1890. *Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.R.C.Inst., F.R.G.S., F.R.E.S., F.S.S., M.R.I.A. 14 Waterloo-road, Dublin.
1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1908. ‡*Worsdell, W. C.* 27 *Flanders-road, Chiswick, W.*
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1901. ‡Worth, J. T. Oakenrod Mount, Rochdale.
1904. §Worthington, A. M., C.B., F.R.S. 1 The Paragon, Blackheath, S.E.
1908. *Worthington, James H., B.A., F.R.A.S. Wycombe Court, High Wycombe.
1906. ‡Wragge, R. H. Vernon. York.
1896. ‡Wrench, Edward M., M.V.O., F.R.C.S. Park Lodge, Baslow, Derbyshire.
1905. ‡Wrentmore, G. G. Marva, Silwood-road, Rondebosch, Cape Colony.
1906. ‡Wright, Sir A. E., M.D., D.Sc., F.R.S. 7 Lower Seymour-street, W.
1905. ‡Wright, Allan. Struan Villa, Gardens, Cape Town.
1883. *Wright, Rev. Arthur, D.D. Queens' College, Cambridge.
1883. *Wright, Rev. Benjamin, M.A. Sandon Rectory, Chelmsford.
1909. §Wright, C. S., B.A. Caius College, Cambridge.
1905. *Wright, FitzHerbert. The Hayes, Alfreton.
1874. ‡Wright, Joseph, F.G.S. 4 Alfred-street, Belfast.
1884. ‡Wright, Professor R. Ramsay, M.A., B.Sc. University College, Toronto, Canada.
1904. ‡Wright, R. T. Goldieslie, Trumpington, Cambridge.
1903. ‡Wright, William. The University, Birmingham.

Year of
Election.

1871. ‡WRIGHTSON, Sir THOMAS, Bart., M.Inst.C.E., F.G.S. Neasham Hall, Darlington.
1902. ‡Wyatt, G. H. 1 Maurice-road, St. Andrew's Park, Bristol.
1901. ‡Wylie, Alexander. Kirkfield, Johnstone, N.B.
1902. ‡Wylie, John. 2 Mafeking-villas, Whitehead, Belfast.
1899. ‡WYNNE, W. P., D.Sc., F.R.S., Professor of Chemistry in the University of Sheffield. 17 Taptonville-road, Sheffield.

1905. ‡Yallop, J. Allan. Alandale, London-road, Sea Point, Cape Colony.
1901. *Yapp, R. H., M.A., Professor of Botany in University College, Aberystwyth.
. *Yarborough, George Cook. Camp's Mount, Doncaster.
1894. *Yarrow, A. F. Campsie Dene, Blanefield, Stirlingshire.
1905. ‡Yerbury, Colonel. Army and Navy Club, Pall Mall, S.W.
1886. *YOUNG, A. H., M.B., F.R.C.S. (Local Sec. 1887), Professor of Anatomy in the Victoria University, Manchester.
1909. §Young, Professor A. H. Woburn P.O., Ontario, Canada.
1904. ‡Young, Alfred. Selwyn College, Cambridge.
1891. §Young, Alfred C., F.C.S. 17 Vicar's-hill, Lewisham, S.E.
1905. ‡Young, Professor Andrew, M.A., B.Sc. South African College, Cape Town.
1909. §Young, F. A. 615 Notre Dame-avenue, Winnipeg, Canada.
1894. *YOUNG, GEORGE, Ph.D. 79 Harvard-court, Honeybourne-road, N.W.
1909. §Young, Herbert, M.A., B.C.L., F.R.G.S. Arnprior, Ealing, W.
1901. *Young, John. 2 Montague-terrace, Kelvinside, Glasgow.
1905. ‡Young, Professor R. B. Transvaal Technical Institute, Johannesburg.
1885. ‡YOUNG, R. BRUCE, M.A., M.B. 8 Crown-gardens, Dowanhill, Glasgow.
1909. §Young, R. G. University of North Dakota, North Chautauqua, North Dakota, U.S.A.
1901. ‡Young, Robert M., B.A. Rathvarna, Belfast.
1883. *YOUNG, SYDNEY, D.Sc., F.R.S. (Pres. B, 1904), Professor of Chemistry in the University of Dublin. 12 Raglan-road, Dublin.
1887. ‡Young, Sydney. 29 Mark-lane, E.C.
1907. *YOUNG, WILLIAM HENRY, M.A., Sc.D., F.R.S. La Nonette de la Forêt, Geneva, Switzerland.
1903. ‡Yoxall, Sir J. H., M.P. 67 Russell-square, W.C.

CORRESPONDING MEMBERS.

Year of Election.

1887. Professor Cleveland Abbe. Local Office, U.S.A. Weather Bureau, Baltimore, U.S.A.
1892. Professor Svante Arrhenius. The University, Stockholm. (Bergsgatan 18.)
1881. Professor G. F. Barker. 3909 Locust-street, Philadelphia, U.S.A.
1897. Professor Carl Barus. Brown University, Providence, R.I., U.S.A.
1894. Professor E. van Beneden, D.C.L. 50 quai des Pêcheurs, Liège, Belgium.
1887. Hofrath Professor A. Bernthsen, Ph.D. Anilenfrabrik, Ludwigshafen, Germany.
1892. Professor M. Bertrand. 75 rue de Vaugirard, Paris.
1894. Deputy Surgeon-General J. S. Billings. 40 Lafayette-place, New York, U.S.A.
1893. Professor Christian Bohr. Bredgade 62, Copenhagen, Denmark.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, U.S.A.
1884. Professor H. P. Bowditch, M.D., LL.D. Harvard Medical School, Boston, Massachusetts, U.S.A.
1890. Professor Dr. L. Brentano. Friedrichstrasse 11, München.
1893. Professor Dr. W. C. Brögger. Universitets Mineralogske Institute, Christiania, Norway.
1887. Professor J. W. Brühl. Heidelberg.
1884. Professor George J. Brush. Yale University, New Haven, Conn., U.S.A.
1894. Professor D. H. Campbell. Stanford University, Palo Alto, California, U.S.A.
1897. M. C. de Candolle. 3 Cour de St. Pierre, Geneva, Switzerland.
1887. Professor G. Capellini. 65 Via Zamboni, Bologna, Italy.
1887. Hofrath Dr. H. Caro. C. 8, No. 9, Mannheim, Germany.
1894. Emile Cartailhac. 5 rue de la Chaîne, Toulouse, France.
1901. Professor T. C. Chamberlin. Chicago, U.S.A.
1894. Dr. A. Chauveau. 7 rue Cuvier, Paris.
1887. F. W. Clarke. United States Geological Survey, Washington, D.C., U.S.A.
1873. Professor Guido Cora. Via Nazionale 181, Rome.
1889. W. H. Dall, Sc.D. United States Geological Survey, Washington, D.C., U.S.A.
1872. Dr. Yves Delage. Faculté des Sciences, La Sorbonne, Paris.
1901. Professor G. Dewalque. 17 rue de la Paix, Liège, Belgium.
1890. Professor V. Dwelshauvers-Dery. 4 quai Marcellis, Liège, Belgium.
1876. Professor Alberto Eccher. Florence.
1894. Professor Dr. W. Einthoven. Leiden, Netherlands.
1892. Professor F. Elfving. Helsingfors, Finland.
1901. Professor H. Elster. Wolfenbüttel, Germany.

Year of Election.

1901. Professor W. G. Farlow. Harvard, U.S.A.
1874. Dr. W. Feddersen. Carolinenstrasse 9, Leipzig.
1886. Dr. Otto Finsch. Altewiekring, No. 19b, Braunschweig, Germany.
1887. Professor Dr. R. Fittig. Strassburg.
1894. Professor Wilhelm Foerster, D.C.L. Encke Platz 3A, Berlin, S.W. 48.
1872. W. de Fonvielle. 50 rue des Abbesses, Paris.
1901. Professor A. P. N. Franchimont. Leiden, Netherlands.
1894. Professor Léon Fredericq. 20 rue de Pitteurs, Liège, Belgium.
1887. Professor Dr. Anton Fritsch. 66 Wenzelsplatz, Prague, Bohemia.
1892. Professor Dr. Gustav Fritsch. Dorotheenstrasse 35, Berlin.
1881. Professor C. M. Gariel. 6 rue Edouard Détaille, Paris.
1901. Professor Dr. H. Geitel. Wolfenbüttel, Germany.
1889. Professor Gustave Gilson. l'Université, Louvain, Belgium.
1889. A. Gobert, 222 Chaussée de Charleroi, Brussels.
1884. General A. W. Greely, LL.D. War Department, Washington, U.S.A.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1876. Professor Ernst Haeckel. Jena.
1881. Dr. Edwin H. Hall. 30 Langdon-street, Cambridge, Mass., U.S.A.
1893. Professor Paul Heger. 23 rue de Drapiers, Brussels.
1894. Professor Ludimar Hermann. Universität, Königsberg, Prussia.
1893. Professor Richard Hertwig. Zoologisches Institut, Alte Akademie, Munich.
1893. Professor Hildebrand. Stockholm.
1897. Dr. G. W. Hill. West Nyack, New York, U.S.A.
1881. Professor A. A. W. Hubrecht, LL.D., D.Sc., C.M.Z.S. The University, Utrecht, Netherlands.
1887. Dr. Oliver W. Huntington. Cloyne House, Newport, R.I., U.S.A.
1884. Professor C. Loring Jackson. 6 Boylston Hall, Cambridge, Massachusetts, U.S.A.
1876. Dr. W. J. Janssen. Villa Polar, Massagno, Lugano, Switzerland.
1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy, Annapolis, Maryland, U.S.A
1887. Professor C. Julin. 153 rue de Fragnée, Liège.
1876. Dr. Giuseppe Jung. Bastions Vittoria 41, Milan.
1884. Baron Dairoku Kikuchi, M.A. Imperial University, Tokyo, Japan.
1873. Professor Dr. Felix Klein. Wilhelm-Weberstrasse 3, Göttingen.
1894. Professor Dr. L. Kny. Kaiser-Allee 186-7, Wilmersdorf, bei Berlin.
1896. Professor F. Kohlrausch. Marburg, Germany.
1894. Professor J. Kollmann. St. Johann 88, Basel, Switzerland.
1894. Maxime Kovalevsky. 13 Avenue de l'Observatoire, Paris, France.
1887. Professor W. Krause. Knesebeckstrasse, 17/1, Charlottenburg, bei Berlin.
1877. Dr. Hugo Kronecker, Professor of Physiology. Universität, Bern, Switzerland.
1887. Professor A. Ladenburg. Kaiser Wilhelmstrasse 108, Breslau.
1887 Professor J. W. Langley. 2037 Geddes-avenue, Ann Arbor, Michigan, U.S.A.
1872. M. Georges Lemoine. 76 rue Notre Dame des Changes, Paris.
1901. Professor Philipp Lenard. Schlossstrasse 7, Heidelberg.
1887. Professor A. Lieben. Molkerbastei 5, Vienna.
1883. Dr. F. Lindemann. Franz-Josefstrasse 12/I, Munich.
1887. Professor Dr. Georg Lunge. Rämistrasse 56, Zurich, V.
1871. Professor Jacob Lüroth. Mozartstrasse 10, and Unversiität, Freiburg-in-Breisgau, Germany.
1894. Professor Dr. Otto Maas. Universität, Munich.

Year of Election.

1887. Henry C. McCook, D.D., Sc.D., LL.D. 3700 Chestnut-street, Philadelphia, U.S.A.
1867. Professor Mannheim. 1 Boulevard Beauséjour, Paris.
1887. Dr. C. A. von Martius. Voss Strasse 8, Berlin, W.
1884. Professor Albert A. Michelson. The University, Chicago, U.S.A.
1887. Dr. Charles Sedgwick Minot. Boston, Massachusetts, U.S.A.
1894. Professor G. Mittag-Leffler. Djursholm, Stockholm.
1897. Professor Oskar Montelius. St. Paulsgatan 11, Stockholm, Sweden.
1897. Professor E. W. Morley, LL.D. West Hartford, Connecticut, U.S.A.
1887. E. S. Morse. Peabody Academy of Science, Salem, Mass., U.S.A.
1889. Dr. F. Nansen. Lysaker, Norway.
1894. Professor R. Nasini. Istituto Chimico, Via S. Maria, Pisa, Italy.
1887. Professor Emilio Noelting. Mühlhausen, Elsass, Germany.
1894. Professor H. F. Osborn. Columbia College, New York, U.S.A.
1890. Professor W. Ostwald. Linnéstrasse 2, Leipzig.
1890. Maffeo Pantaleoni. 13 Cola di Rienzo, Rome.
1895. Professor F. Paschen. Universität, Tübingen.
1887. Dr. Pauli. Feldbergstrasse 49, Frankfurt a/Main, Germany.
1901. Hofrath Professor A. Penck. Georgenstrasse 34–36, Berlin, N.W. 7.
1890. Professor Otto Pettersson. Stockholms Hogskola, Stockholm.
1894. Professor W. Pfeffer, D.C.L. Linnéstrasse 11, Leipzig.
1870. Professor Felix Plateau. 152 Chaussée de Courtrai, Gand, Belgium.
1886. Professor F. W. Putnam. Harvard University, Cambridge, Massachusetts, U.S.A.
1887. Professor Georg Quincke. Hauptstrasse 47, Friederichsbau, Heidelberg.
1868. L. Radlkofer, Professor of Botany in the University of Munich. Sonnenstrasse 7.
1895. Professor Ira Remsen. Johns Hopkins University, Baltimore, U.S.A.
1897. Professor Dr. C. Richet. 15 rue de l'Université, Paris, France.
1896. Dr. van Rijckevorsel. Parklaan 3, Rotterdam, Netherlands.
1892. Professor Rosenthal, M.D. Erlangen, Bavaria.
1890. Professor A. Lawrence Rotch. Blue Hill Observatory, Hyde Park, Massachusetts, U.S.A.
1895. Professor Carl Runge. Wilhelm Weber-strasse 21, Göttingen, Germany.
1901. Gen.-Major Rykatchew. Central Physical Observatory, St. Petersburg.
1894. Professor P. H. Schoute. The University, Groningen, Netherlands.
1874. Dr. G. Schweinfurth. Potsdamerstrasse 75A, Berlin.
1897. Professor W. B. Scott. Princeton, N.J., U.S.A.
1892. Dr. Maurits Snellen. Apeldoorn, Pays-Bas, Holland.
1887. Professor H. Graf Solms. Botanischer Garten, Strassburg.
1887. Ernest Solvay. 25 rue du Prince Albert, Brussels.
1888. Dr. Alfred Springer. 312 East 2nd-street, Cincinnati, Ohio, U.S.A.
1889. Professor G. Stefanescu. Strada Verde 8, Bucharest, Roumania.
1881. Dr. Cyparissos Stephanos. The University, Athens.
1894. Professor E. Strasburger. The University, Bonn.
1881. Professor Dr. Rudolf Sturm. Weyderstrasse 9, Breslau.
1887. Dr. T. M. Treub. Buitenzorg, Java.
1887. Professor John Trowbridge. Harvard University, Cambridge, Massachusetts, U.S.A.
Arminius Vambéry, Professor of Oriental Languages in the University of Pesth, Hungary.

Year of Election.

1890. Professor Dr. J. H. van't Hoff. Uhlandstrasse 2, Charlottenburg, Berlin.
1889. Wladimir Vernadsky. Imperial Academy of Sciences, St. Petersburg.
1886. Professor Jules Vuylsteke. 21 rue Belliard, Brussels, Belgium.
1887. Professor H. F. Weber. Zurich.
1887. Professor Dr. Leonhard Weber. Moltkestrasse 60, Kiel.
1887. Professor August Weismann. Freiburg-in-Breisgau, Baden.
1887. Dr. H. C. White. Athens, Georgia, U.S.A.
1881. Professor H. M. Whitney. Branford, Conn., U.S.A.
1887. Professor E. Wiedemann. Erlangen.
1887. Professor Dr. R. Wiedersheim. Hansastrasse 3, Freiburg-im-Breisgau, Baden.
1887. Dr. Otto N. Witt. Ebereschen-Allée 10, Westend bei Berlin.
1896. Professor E. Zacharias. Botanischer Garten, Hamburg.
1887. Professor F. Zirkel. Königstrasse 2A, Bonn-am-Rhine.

LIST OF SOCIETIES AND PUBLIC INSTITUTIONS

TO WHICH A COPY OF THE REPORT IS PRESENTED.

GREAT BRITAIN AND IRELAND.

Belfast, Queen's College.
Birmingham, Midland Institute.
Bradford Philosophical Society.
Brighton Public Library.
Bristol Naturalists' Society.
——, The Museum.
Cambridge Philosophical Society.
Cardiff, University College.
Chatham, Royal Engineers' Institute.
Cornwall, Royal Geological Society of.
Dublin, Geological Survey of Ireland.
——, Royal College of Surgeons in Ireland.
——, Royal Irish Academy.
——, Royal Society.
Dundee, University College.
Edinburgh, Royal Society of.
——, Royal Medical Society of.
——, Scottish Society of Arts.
Exeter, Royal Albert Memorial College Museum.
Glasgow, Royal Philosophical Society of.
——, Institution of Engineers and Shipbuilders in Scotland.
Leeds, Institute of Science.
——, Philosophical and Literary Society of.
Liverpool, Free Public Library.
——, Royal Institution.
——, The University.
London, Admiralty, Library of the.
——, Chemical Society.
——, Civil Engineers, Institution of.
——, Geological Society.
——, Geology, Museum of Practical.
——, Greenwich, Royal Observatory.
——, Guildhall, Library.
——, Institution of Electrical Engineers.
——, Institution of Mechanical Engineers.
——, King's College.
London, Linnean Society.
——, London Institution.
——, Meteorological Office.
——, Physical Society.
——, Royal Anthropological Institute
——, Royal Asiatic Society.
——, Royal Astronomical Society.
——, Royal College of Physicians.
——, Royal College of Surgeons.
——, Royal Geographical Society.
——, Royal Institution.
——, Royal Meteorological Society.
——, Royal Society.
——, Royal Society of Arts.
——, Royal Statistical Society.
——, Royal Sanitary Institute.
——, United Service Institution.
——, University College.
——, War Office, Library.
——, Zoological Society.
Manchester Literary and Philosophical Society.
——, Municipal School of Technology.
Newcastle-upon-Tyne, Literary and Philosophical Society.
——, Public Library.
Norwich, The Free Library.
Nottingham, The Free Library.
Oxford, Ashmolean Natural History Society.
——, Radcliffe Observatory.
Plymouth Institution.
——, Marine Biological Association.
Salford, Royal Museum and Library.
Sheffield, University College.
Southampton, Hartley Institution.
Stonyhurst College Observatory.
Surrey, Royal Gardens, Kew.
——, National Physical Laboratory (Observatory Department).
Swansea, Royal Institution of South Wales.
Yorkshire Philosophical Society.
The Corresponding Societies.

EUROPE.

Berlin ....Die Kaiserliche Akademie der Wissenschaften.
Bonn ....University Library.
Brussels ....Royal Academy of Sciences.
Charkow ....University Library.
Coimbra .....Meteorological Observatory.
Copenhagen...Royal Society of Sciences.
Dorpat, Russia University Library.
Dresden ....Royal Public Library.
Frankfort ...Natural History Society.
Geneva.......Natural History Society.
Göttingen ....University Library.
Grätz ....Naturwissenschaftlicher Verein.
Halle ....Leopoldinisch-Carolinische Akademie.
Harlem ......Société Hollandaise des Sciences.
Heidelberg....University Library.
Helsingfors ...University Library.
Jena ....University Library.
Kazan, Russia University Library.
Kiel ....Royal Observatory.
Kiev ....University Library.
Lausanne ....The University.
Leiden ....University Library.
Liège ....University Library.
Lisbon ....Academia Real des Sciences.
Milan ....The Institute.
Modena ......Royal Academy.
Moscow ......Society of Naturalists.
Moscow ......University Library.
Munich.......University Library.
Naples ....Royal Academy of Sciences.
Paris.........Association Française pour l'Avancement des Sciences.
—— ....Geographical Society
—— ....Geological Society.
—— ....Royal Academy of Sciences.
—— ....School of Mines.
Pultova ......Imperial Observatory.
Rome ....Accademia dei Lincei.
—— ....Collegio Romano.
—— ....Italian Geographical Society.
—— ....Italian Society of Sciences.
Roumania ..Roumanian Association for the Advancement of Science.
St. Petersburg. University Library.
—— ....Imperial Observatory.
Stockholm ...Royal Academy.
Turin ....Royal Academy of Sciences.
Upsala ......Royal Society of Science.
Utrecht ......University Library.
Vienna ......The Imperial Library.
—— ....Central Anstalt für Meteorologie und Erdmagnetismus.
Zurich........Naturforschende Gesellschaft.

ASIA.

Agra ....The College.
Bombay .....Elphinstone Institution.
—— ....Grant Medical College.
Calcutta .....Asiatic Society.
—— ....Hooghly College.
Calcutta .....Medical College.
—— ....Presidency College.
Ceylon ....The Museum, Colombo.
Madras ......The Observatory.
—— ....University Library.
Tokyo ....Imperial University.

AFRICA.

Cape Town ....The Royal Observatory.
—— ....South African Association for the Advancement of Science.
—— ....South African Public Library.
Kimberley ....Public Library.

AMERICA.

Albany ......The Institute.
Amherst......The Observatory.
Baltimore ....Johns Hopkins University.
Boston ......American Academy of Arts and Sciences.
—— ....Boston Society of Natural History.
California.....The University.
—— ......Lick Observatory.
—— ......Academy of Sciences.
Cambridge ...Harvard University Library.
Chicago ......American Medical Association.
—— ....Field Museum of Natural History.
Kingston .....Queen's University.
Manitoba ....Historical and Scientific Society
—— ....The University.
Massachusetts .Marine Biological Laboratory, Woods Holl.
Mexico ......Sociedad Científica 'Antonio Alzate.'
Missouri .....Botanical Garden.
Montreal .....Council of Arts and Manufactures.
—— ......McGill University.
New York ...American Society of Civil Engineers.
—— ....Academy of Sciences.
Ottawa.......Geological Survey of Canada.
Philadelphia ..American Philosophical Society.
—— ....Franklin Institute.
—— ....University of Pennsylvania.
Toronto .....The Observatory.
—— ....The Canadian Institute.
—— ....The University.
Washington...Bureau of Ethnology.
—— ....Smithsonian Institution.
—— ....The Naval Observatory.
—— ....United States Geological Survey of the Territories.
—— ....Library of Congress.
—— ....Board of Agriculture

AUSTRALIA.

Adelaide ....The Colonial Government.
—— ....The Royal Geographical Society.
Brisbane ....Queensland Museum.
Melbourne ....Public Library.
Sydney ....Public Works Department.
—— ....Australian Museum.
Tasmania ....Royal Society.
Victoria............The Colonial Government.

NEW ZEALAND.

Canterbury ....The Museum.
Wellington ....New Zealand Institute.

PRINTED BY
SPOTTISWOODE AND CO. LTD., LONDON
COLCHESTER AND ETON